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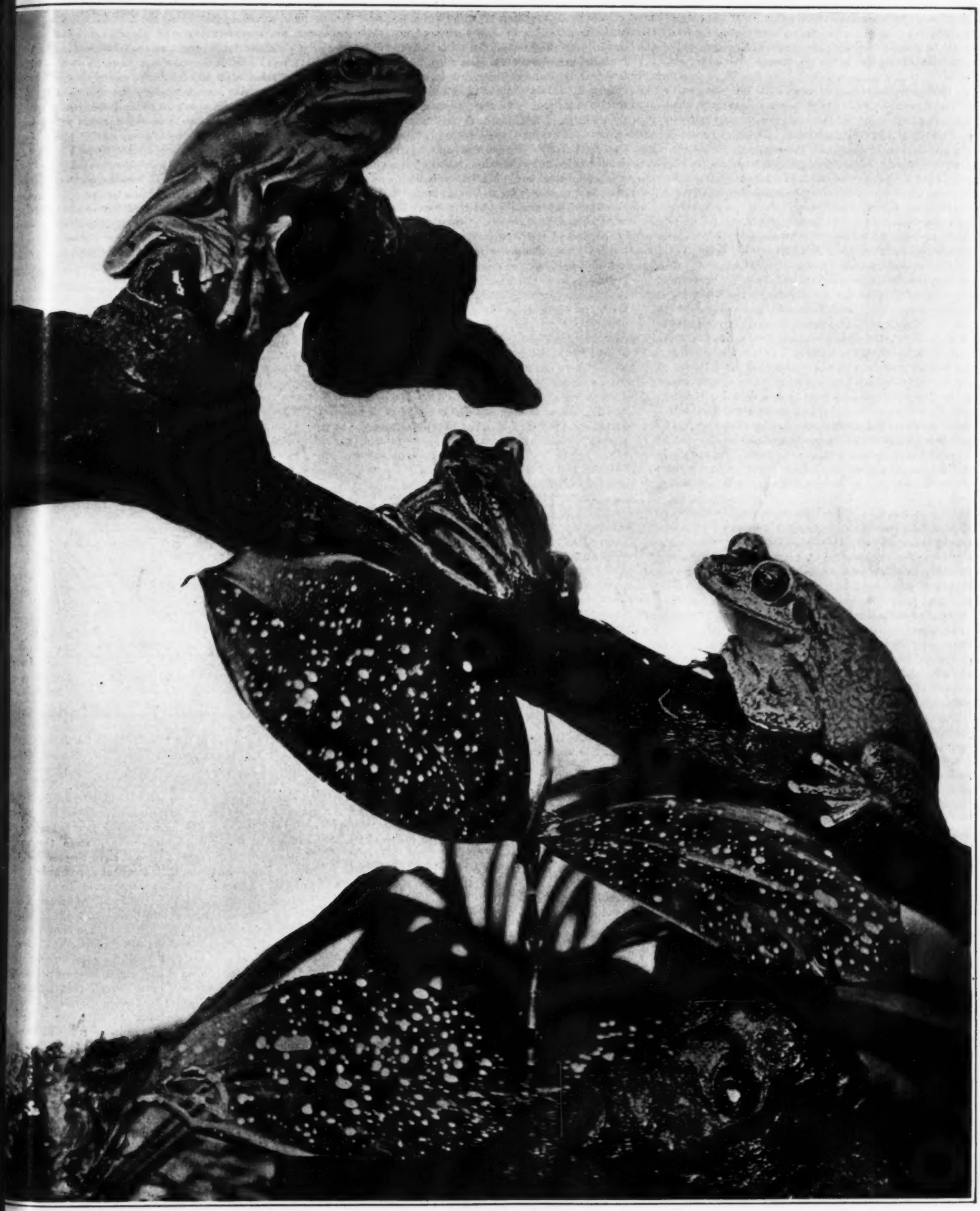


White tree toad. Golden tree toad. Giant tree toad.

SOME RARE TOADS AT THE NEW YORK ZOOLOGICAL PARK.—[See page 196.]

Geographic Aspects of the War—I*

How Topographical Conditions Affect Military Operations

By Prof. Douglas Wilson Johnson

EVERY military campaign is controlled to some extent by the surface features of the country over which the contending armies must move. Both detailed movements of troops and general plans of campaign must be ordered with due regard to topography; and the geographer who reads the war dispatches with a good assortment of large-scale topographic maps before him will perceive many evidences of the rôle played by land forms in military operations.

It need hardly be explained that while the best maps show the topography with a high degree of accuracy, the official reports of troop positions are always very generalized and often purposely incorrect. Despite this limitation, the careful student can learn enough to justify a study of the war from the physiographic standpoint. The object of the present article is to present a picture of the surface upon which the western campaign has been conducted and to note incidentally some relations between topography and military movements.

I.—THE WESTERN THEATER OF WAR.

The geologic architecture of western Europe is the key to its salient topographic features. A broad area of folded and broken rocks was beveled across by erosion, and upon the flat plain thus formed horizontal layers of clay, sandstone, chalk and limestone were deposited. The whole mass was then warped upward around the edges so as to produce a gigantic saucer or basin, known to geographers as the "Paris Basin." From those parts of the basin's margin which were bent upward to the greatest heights erosion has removed the rock covering layers and exposed the underlying folded beds, which have in their turn been carved into mountain ridges and valleys. Among the marginal areas of uplifted and dissected older rocks are the Vosges Mountains on the east and the Ardennes on the north.

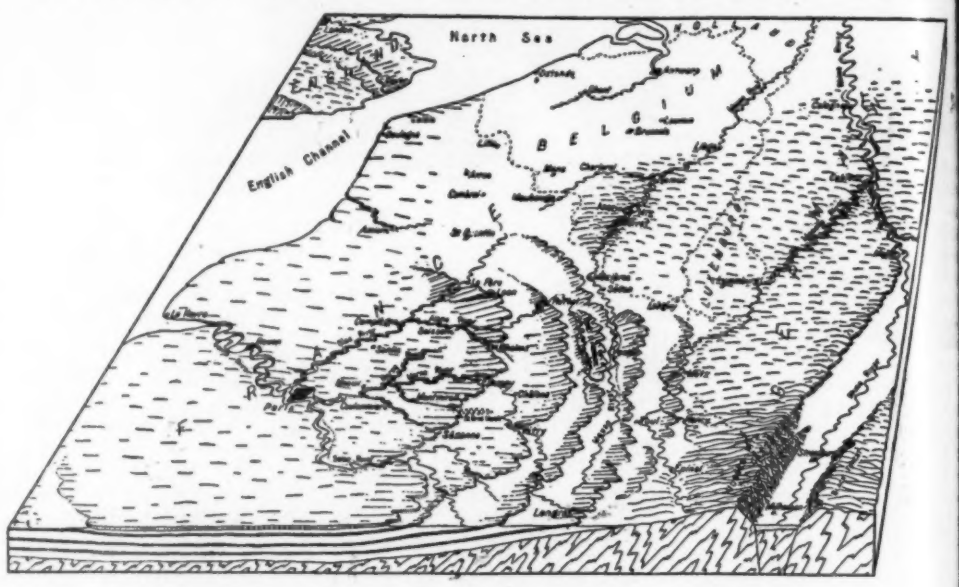
As the most important activities in the present war have thus far occurred in the northeastern portion of the basin just described, we may give our further attention exclusively to this area. The accompanying illustration shows a rectangular block of the earth's crust, which we may imagine as cut out and isolated for greater convenience of study. It represents the northeastern quadrant of the Paris Basin and some adjacent territory. Without making any pretension to accuracy, the diagram will serve to emphasize those elements of surface form essential to an understanding of the campaign against France and Belgium.

One readily observes, for example, that south of Paris the layers of sandstone and other stratified rocks are nearly horizontal, but that they slope upward very gently to the west and east to form the rims of the basin. It will be seen, also, that the underlying folded rocks come to the surface at the east, forming mountains from which the later beds have been completely eroded. Originally this eastern rim of the basin was a broad north-south arch, with a gently rounded summit; but a north-south block of rock extending along the crest, and bounded by two parallel fractures, dropped down several thousand feet giving the broad, flat-floored valley of the middle Rhine. The fertile plains of this valley floor constitute that part of the province of Alsace which the French are most anxious to recover from the Germans.

The two remaining limbs of the former arch, facing inward toward the down-dropped central strip, are known as the Vosges Mountains and the Black Forest. Each of these ranges has a gentle back slope away from the valley, and a steep face toward the valley representing the nearly vertical fracture surface now eroded into sharp crested ridges and narrow ravines. Both slopes of each range are sufficiently rugged to make agriculture difficult and the building of roads and railroads expensive; hence the ranges are but little developed, and much forested land remains. But it is on the steeper slopes which lead abruptly downward to the flat floor of the Rhine Valley that the ridges are most rugged and the forest most unbroken. Here the movement of large bodies of troops is particularly difficult, especially if they must ascend the slopes in the face of a determined enemy.

It was not political expediency alone which led the French to invade southern Alsace at the beginning of the war. The international boundary line follows the crest of the southern Vosges, and it was much easier for the French to move up the gentle west slope of the Vosges, capture the passes and then sweep down the steep eastern face upon the flat plains about Mülhausen than it was for them to cross the boundary further northwest, where no such advantage was furnished by the topography. A French soldier, writing home from the battle line in the Vosges, described the influence of topography upon the fighting in that district in the following words: "Our task has been much easier in the southern Vosges than farther north. In the south it is all downhill after we cross the border; but in the north we must fight uphill against the Germans after we have entered their territory, as there the boundary line lies west of the mountain crest."

It is stated in press reports that a commander of German forces at Mülhausen, ordered to lead his men across the Vosges Mountains into France, made three futile attempts to carry the heights of the range in the face of French artillery. Then came an urgent message from the Kaiser: "The crest of the Vosges must be crossed at any cost." A fourth desperate assault by the intrepid commander ended in his defeat. Retiring to his quarters, the unhappy general committed suicide, first sending to his Kaiser this message: "The Vosges cannot be crossed. Come and try it yourself." I cannot vouch for the truth of this report; but it serves to illustrate the peculiar surface features of the Vosges which render their ascent comparatively easy from the French side of the border but very difficult from the German side.



Block diagram showing topographic features of West Central Europe.

In this connection it is interesting to note that should the French succeed in pushing the Germans back to the east side of the Rhine, their further eastward advance in southern Germany would then be opposed by precisely the same topographic difficulties which have long retarded the westward movement of the Germans in southern Alsace. The Black Forest will replace the Vosges in immediate importance, and while the Germans hold the crest and more gentle eastward slope of this range the French will find assaults against the steep west-facing scarp both costly and difficult.

Not far south of Mülhausen, but beyond the limits of the drawing, the Vosges Mountains descend to a low pass which connects the Rhine Valley with the valley of the Soane in Eastern France. In this pass, guarding the strategic gateway from one valley to the other, stands the mighty fortress at Belfort, the southermost of the great fortifications erected against a German invasion. Entrance to France by this route is easy, so far as the natural physical features alone are concerned; and in the commercial intercourse between the two nations the gateway has played an important rôle. But the opening is narrow enough to be effectively defended by the fortress in its center and to permit the concentration of troops in such numbers as to render its passage by an invader extremely difficult. Whether the fortress which withstood the attacks of the Germans in 1870 can defy the guns which reduced Liege, Namur, Maubeuge and Antwerp will be determined only in case the Germans can push the French field army back far enough to bring the Krupp guns within range of the walls of Belfort.

North and west of the Vosges Mountains the older series of folded rocks, exposed at the surface around the margin of the Paris Basin, have not been raised so high as in the Vosges. Instead they form an upland of but moderate elevation, which was once a nearly level erosion plane; but which, since the uplift, has been cut into hills and valleys by many branching streams. This hi country is known as the Slate Mountains, the Haardt, t Eifel, and by other names in Germany, and as the A dennes in southern Belgium. Although usually d scribed as mountainous, the most striking feature of th area is the remarkably even sky-line which appears every distant landscape view, and which is proof th the much folded rocks were once worn down to a surfa of faint relief, after which warping raised the surface to i present position and permitted its dissection by riv erosion. The upland is now so badly cut up by strea that cross-country travel is difficult, and transportati lines tend to follow the valleys.

Two main rivers cut across this upland toward th northeast—the Moselle and the Meuse; while the lo Rhine transects it from southeast to northwest. Ev dently two armies with headquarters at Coblentz a Cologne, and supplied by the railways, auto roads a steamer routes which pass through the Rhine Gorg could attack France simultaneously if one ascended th Moselle to Luxemburg and the other passed from C logne westward around the north side of the hilly count

Now, let us return to the inner part of the Basin, where the horizontal stratified rocks still cover the older and complexly folded beds. The rock layers of the stratified series are of unequal hardness, and it will be observed from the diagram that wherever a resistant layer comes to the surface it forms a line of cliffs, while the intervening weaker layers have been eroded into broad valley lowlands. If the basin structure were perfect, the upwarped edges of each resistant layer would form a circular line of cliffs extending all the way around Paris. As it is, the rudely circular arrangement of the cliffs is very noticeable, although they are not everywhere developed.

It will be seen that the cliffs face outward, away from the center of the basin, while from their crests the upland surfaces slope gently inward, toward Paris. It is these uplands which are referred to as "plateaus" in the newspaper despatches. They differ from typical plateaus in

* *Bulletin* of the American Geographical Society.

g one steep slope and one gentle slope, and are known ographers as "cuestas." Because the steeper side e cuesta is always away from Paris, an enemy ap- ching that city from the east would have to ascend escarpments under the fire of the defenders' guns, reas the army of defense could manuever its troops dvantage on the upland above, or retire down the e back slope while a small rear guard delayed the t of a victorious invader. During the Battle of the e the German center near Sèzanne is said to have subjected to a disastrous fire from French artillery d along the crest of the first line of cliffs east of , a position which effectively commanded the open s of the broad lowlands of Chalons just east of the pment. For months a German army operating st Verdun from the lowland of the Woevre district tried in vain to ascend the line of cliffs east of that rtant fortified city; and at the time these lines are en they have only succeeded in gaining a precarious old farther south, where the escarpment is partly n down by more effective erosion. According to best available information, the Verdun forts have not active in repelling the German attacks; but the ch field army, aided by the topographic advantage, eld the Germans out of range of the forts.

e only instances in which a cuesta is bordered by on the side toward Paris occur where a river has d a valley in the upland, west of the main cliff-face parallel to it. Examples of this are found at Verdun re the Meuse River flows through the back slope of a ta, and west of Verdun where the upper Aisne River a similar course. The west-facing cliffs are merely astern walls of the river valleys; and it will be seen the Forêt d'Argonne, where stiff fighting has oc- d both in this and in other wars, is a long and com- atively inaccessible tableland formed by that part of a ta lying east of the valley of the upper Aisne.

is true that some rivers cut across the cuestas from lowland to another, giving a limited number of easy es through the lines of cliffs. But the openings are her wide enough nor numerous enough to offset the fective effect of the east-facing escarpments. Fur- rmore, these passes are easily guarded by fortifica- s, the individual forts being located both in the val- and in commanding positions on the adjacent up- ds. Thus, at La Fère, Laon, Rheims and Soissons, ch guard the openings through the inner line of cliffs he Oise River Valley and Paris, the projecting spurs he upland are crowned by forts whose guns frown n upon each valley gateway from various points of the pass. A large proportion of the places whose names d the news columns during the German advance on is and the retreat to the Aisne are strategic points use they guard important openings through the sta escarpments. In adition to the four named ve, one might mention Épernay, Sézanne, Rethel, y-le-François, Nancy, Toul, Epinal and Metz, not to tion others which have figured less prominently in press reports.

The gap at Toul is not now occupied by any river; the upper Moselle formerly flowed through this ning into the Meuse River, until it was diverted to its ent course. The abandoned valley through the s is of such strategic importance that it is protected one of the strongest fortifications in France. At anne is another gap abandoned by the stream which ved it; but in this case the capture of the former river one of its neighbors occurred so long ago that the gap d not been cut to any considerable depth or width; ce this route, although used by an important railway, ot of such great strategic value. A third gap carved a river which has since been diverted to a new course found just north of Sézanne; and the St. Gond Marsh, ere German artillery became mired during the retreat ich followed the successful French attack upon the rman center between Sézanne and Vitry, is caused stagnant water occupying the abandoned valley of the erted stream.

Toward the northwest the successive lines of cliffs crease in height and finally disappear. Further north e plain of Holland and northern Belgium, formed in rt by the delta deposits of the Rhine and other rivers, ches the sea at an altitude so low that only dykes pre- nt its marginal areas from being submerged at high e. The Belgians have repeatedly taken advantage this topographic feature, as when they retarded the ge of Antwerp by opening the dykes and flooding the untry adjacent to the city, and during the Battle of e Yser, when they flooded the lower part of the Yser lley and forced a German retreat. Even where the ain is not low enough to be submerged it is remarkably e from topographic inequalities of any magnitude. e river valleys are shallow, and the valley walls slope y gently upward to the level surface of the plain. ood roads and railways are numerous, and the forests ve been largely removed in order to devote the fertile d to agriculture. The plain is not only admirably apted to the rapid movement of great masses of troops, t is productive enough to sustain large armies for a long period. It is a part of the vast lowland extending from southwestern France to northeastern Russia, over which one may travel the entire distance by rail without passing through a single tunnel and without rising 600 feet above the level of the sea. Its remarkably flat surface is the most striking characteristic of landscape views of central and western Belgium.

It is interesting to consider Germany's breach of Belgian neutrality in the light of the topography as described above. A glance at the accompanying diagram will show that four principal routes of invasion were open to her. She could concentrate her forces in the southern part of the broad valley of the middle Rhine and thence ascend the steep eastern face of the Vosges Mountains or pass around their northern end across the dissected upland of Lorraine, or around their southern end through the narrow gateway guarded by the fortifications of Belfort. If these obstructions were successfully passed, the invading armies would then have to scale in succession one line of east-facing cliffs after another, under the fire of artillery directed against them from every projecting spur of the escarpment and from the head of every ravine cut back in its face. To perfect their lines of communication, the fortresses protecting the openings through the cliffs would have to be leveled as the troops advanced. The engineering problems involved in supplying a large army and in moving heavy siege guns would be far more serious in a country broken by such escarpments than on a level plain where new transportation routes are readily constructed at will. Germany could scarcely hope to make a dashing attack on Paris by this southern route, even were the fortifications here no more formidable than those farther north. The topography alone would enable the French to render the advance of an invader slow and costly.

An advance up the Moselle by way of Metz would obviate the necessity of crossing the escarpment of the Vosges; and if the army turned southwest through Luxemburg it would avoid still more of the topographic difficulties of eastern France. But, as appears from the diagram, most of the cuesta escarpments would still have to be crossed on the way to Paris, and this route is open to the same objections, although to a lesser degree, as the more southern one.

The two remaining routes lie through Belgium. The one up the Meuse through the Ardennes involves the destruction or masking of the forts on the uplands overlooking the valley at Namur and other points; but once in French territory the cuestas could be crossed where they are dying out toward the northwest, and the march on Paris could be made over a country much easier to traverse than that farther east. Less direct, but still more favorable for the movement of armies, is the route across the level plains farther north in Belgium, by way of Louvain, Brussels and Mons into the slightly dissected plain of northern France near Cambrai and St. Quentin. Here an army could avoid every important topographic obstacle until the broad valley of the Seine was reached. Even if the taking of La Fére and Laon were necessary, these fortifications mark the innermost cliff line next to Paris and are located where that escarpment is dying out toward the northwest to disappear entirely.

It is highly significant that the main invasion of France was by the most roundabout but topographically most favorable route. The distance from the nearest point on the Franco-German boundary, near Metz, to Paris is about 170 miles as the aeroplane flies. From the German-Belgian border to Paris via the Belgian plain the distance is approximately 250 miles. Germany therefore selected a route which was nearly 50 per cent longer than that directly from her own territory into France. The longer route involved the violation of Belgian neutrality, and to follow it would very probably bring into the conflict the Belgian army, and possibly the army and navy of Great Britain. Surely the choice of an invasion through Belgium must have been dictated by very compelling reasons to justify it in the minds of the German general staff. The official statement that the crossing of Belgian territory was "a matter of life and death" to Germany was literally true. An advance from the Franco-German boundary across the cuestas of the Paris Basin would undoubtedly have required the sacrifice of an added number of German lives, and would have made impossible the contemplated rapid dash to Paris.

Germany was compelled to choose between keeping her international pledges at the expense of crossing unfavorable topography and breaking those pledges in order to profit by a more favorable route. She chose the latter course. Without touching on the ethical questions involved, we may note that for political reasons the violation of Belgian neutrality has undoubtedly proved more costly than would have been the crossing of the escarpments of northeastern France.

II.—THE EASTERN CAMPAIGN.

It is the object of the present paper to present a picture of the broader topographic features of that portion of eastern Europe traversed by the Russian and Austro-German forces, and to discuss the influence of this topography upon the plans of campaign and the movements of armies during the first six months of the war. As in the former paper, the more striking surface forms are represented by a block diagram, which makes no pretension to accuracy, so far as details are concerned, but which will assist the reader in grasping the more important topographic elements of the region.

General Physiography. A rectangular area, including East Prussia on the north, Poland in the middle, and Galicia on the south, is all we need here consider. Across the southern border of the area the Carpathian Mountains curve eastward and southeastward in a great arc. Along the middle portion of their course they consist of a belt of maturely dissected folded mountains, sixty miles wide, in which long parallel ridges of resistant sandstones remind an American of the folded Appalachians, while subsequent streams have eroded parallel valleys along the weaker beds. The parallelism of topographic elements is most pronounced along the northeast side of the belt; and the Carpathians differ from the American system in being more massive along the southwestern side, where crystalline rocks appear, while a somewhat irregular crestline of greater altitude separates the two dissimilar areas. Like the American ridges, those of the Carpathians are well forested.

No rivers cut across the crest line in this part of the range, but half a dozen fairly accessible passes, from 1,200 to more than 2,000 feet high, permit roads and railroads to cross from the low plain of Hungary on the southwest to the plains of Galicia on the northeast. Among these we have heard most frequently of the Dukla, Lupkow and Uzsok Passes, because of their peculiar strategic importance. Along the northeastern base of the Carpathians we may note the location of three cities: Jaroslaw and Przemysl near the center of the arc, two important fortress cities, access to which from Hungary is commanded by the three passes just mentioned; and Cracow, another fortified city near the head of the Vistula Valley, whence easy gateways open into Austria and by way of the Oder Valley into Silesia.

Many rivers flow northward and northeastward from the Carpathian crest across the parallel ridges and the Galician plain. Among these transverse streams the Raba, Dunajec, Biala, Wisloka and Wislok have fairly open valleys throughout their middle and lower courses in the mountains, and have developed good meanders on the valley floors. The San is the most easterly of the important streams which enter the Vistula, and has an entrenched meandering course until it leaves the mountains at Przemysl to turn abruptly northwest past Jaroslaw as a normal late mature river meandering extensively on a broad, marshy flood-plain, slightly entrenched below the level of the Galician plain. To the southeast the remaining transverse streams flow in parallel lines to the Dniester, whose upper course meanders on a very broad flood-plain which is even more swampy than that of the lower San; while farther down the river is the deeply entrenched Dniester gorge. We should expect that the streams which debouch from the mountains would deposit some of their load of débris and thus tend to build up an alluvial piedmont slope inclining gently away from the mountain base. The topography suggests the presence of such an inclined alluvial plain; but it is evident that its formerly smooth surface has been much dissected by later entrenching of the stream courses, and the extent to which the older beds are masked by the alluvium is not clear. The Dniester and San appear to have had their courses determined by the intersection of this northeastward sloping piedmont plain with another southward or southwestward sloping plain described below.

The rocks which are strongly folded in the Carpathians suddenly flatten out toward the northeast and north to form the great plain of Galicia and Poland. The topography is not laways that of perfectly horizontal rocks, however, but betrays the presence over broad areas of moderate dips toward the mountains. Thus in eastern Galicia there is a splendid cuesta with its gentle back slope inclined southward obliquely toward the range, while on the north the steep erosion scarp faces north or northeast toward a broad lowland eroded by the headwaters of the Bug and Styr Rivers. This cuesta is known as the Podolian Plateau, and the rivers flowing southward down the gentle back slope have cut deep gorges, which are remarkable for their straightness and their parallel arrangement. Toward Przemysl the rocks of the Podolian Plateau appear to change to a southwestward dip, and the steep erosion escarpment bends abruptly toward the northwest. At the base of the escarpment, near the angle where the line of cliffs changes from a northeast-southwest to a southeast-northwest direction, lies the city of Lemberg, guarding a strategic gateway or low pass from the Bug lowland through the cuesta to the San-Dniester lowland and Przemysl. Farther northwest, Rawaruska occupies a similar position. At both points strategic railways cross through the cuesta from one lowland to the other.

(*To be concluded.*)

Some Rare Amphibians*

Valuable New Specimens at the New York Zoological Park

By Raymond L. Ditmars

White tree toad (upper), Natterjack toad (middle), Marine toad (bottom).

For years past the Reptile House has been noted as a building of silent inmates. Days might pass when the only sounds were the splashing of the alligators or an occasional bull-like bellow from these great reptiles. The Reptile House has changed its aspect in now sheltering quite a number of more cheerful voiced inmates. These are the toads and frogs, and to this collection we lately have added a number of rare and particularly interesting species. The greater number of these have never been exhibited alive in the United States. The noisy members of this collection are mostly tree toads, and each species has a characteristic and markedly different note.

For about three years we have been steadily building up a series of amphibians until the Reptile House has now one of the best collections on exhibition in the world. Our visitors are always especially interested in investigating the contents of many small, attractively labeled cages, and it is under such conditions only that the small amphibians necessarily can be maintained.

At the present time there are thirty-seven cages of amphibians—frogs, toads, salamanders and newts—on exhibition in the park, and about seventy species of the amphibians are represented. An interesting list of the species on exhibition at the close of the year 1914 appeared in the *Nineteenth Annual Report* on pages 85, 86, and 87.

New to our collections is the huge White Tree Toad of Australia, which attains a body length of five inches. The species is particularly interesting on account of its peculiar call, which resembles the barking of a small dog, and is repeated twenty times or more. The creature is of a vivid and uniform leaf green with enormously dilated disks or suckers upon fingers and toes. It consequently has unusual clinging power, and the keepers in changing these toads from one cage to another must use great care not to injure the delicate animals in loosening their hold. Contrary to the habits of tree toads generally, this one is a very confiding creature and, when once freed from a branch to which it has been clinging, appears to have no objection to being handled and will contentedly settle down on the keeper's hand, tucking its huge feet beneath its body in an attitude of perfect contentment.

Occupying the same cage with the big green tree toads is another species from Australia of remarkably brilliant coloration—one of the most attractive of its race. This is the beautiful Golden Tree Toad. It is a large species of over three inches in length of body, of a bright metallic green broadly barred or blotched with a hue as vivid as bronze paint. When chilled, the entire color pattern may fade to a dull, blotchy-brown. In form this species is much like the typical frogs of the genus *Rana*. We have never heard the voice of this handsome species, but its silence is quite counterbalanced by the specimens of the Perron Tree Toad in an adjoining cage. This is another Australian species and emits a startling call that much resembles the sound made by a pneumatic riveting machine. When the animal sings the throat pouch is expanded into a large and translucent globe larger than the toad's head, while the body vibrates with the effort of the call. Other noteworthy tree toads in the collection are the Baudin Tree Toad, collected in Costa Rica by Assistant Curator Crandall, and the Giant Tree Toad of the West Indies and Bahamas. The latter specimen was collected by Curator Engelhardt of the Brooklyn Institute of Arts and Sciences. The West Indian species is the largest of the New World tree toads. It is not only cannibalistic, but will eat small birds, mice, and even small snakes.

Aside from the noteworthy series of frogs and toads, we have now on exhibition a very interesting collection of the tailed amphibians, the salamanders and their allies. We have maintained specimens of the Blind Proteus, a strictly aquatic salamander, for a period of about two years. These curious creatures come from the subterranean rivers of the Adelsberg Cave, in Austria. The eyes are indicated by mere depressions with a sunken dot of color, although in the larval form the eye is at first well developed. If kept in a strong light these sensitive creatures do not fare well. We paint three sides of their tank with opaque black, leaving the front panel clear for observation. After a few months' time the light through the single panel markedly affects these animals' skin. At first they are of a pale cream color, but they gradually change to a dull, slaty hue. Their food consists of very small earthworms. In motion the diminutive limbs are little used, the creature propelling its elongate body with eel-like motions.

Several specimens of a remarkable land salamander recently arrived from the west represent a species known technically as *Batrachoseps caudatus*. This is popularly known as the Worm Salamander and is probably the most excessively elongate form among any of the terrestrial salamanders. Our examples are from four to five inches long with limbs so minute and delicate that the animal's progress is of almost snail-like pace. This curious salamander has a most northerly distribution, being found from California into Alaska.

Keeper Deckert last fall added specimens of an interesting salamander to the collection. This is the Jefferson Salamander, *Amblystoma jeffersonianum*, a very slender form of *Amblystoma* and rarely obtained from the eastern coastal region. Its habitat is the Allegheny region, but Mr. Deckert collected four specimens near White Plains, Westchester County, New York.

The huge White Tree toad, a native of Australia.

All forms of the axolotl are now shown in our collection, both black and albino of the water form, and the western and eastern forms of the terrestrial type. The boldy marbled form from Long Island is of especial interest. Our western specimens came from Arizona and show but slight traces of pattern.

When To Clean Turbine Blades.

As a result of impure feed water for the boiler scale is liable to form on the blades of turbine motors and when this occurs to any appreciable extent it is necessary to clean the blades, as the scale diminishes the efficiency of the motor. In an electric light station in this country the condition of the blades is ascertained by observation of the steam-flow meter connected with the intake of the turbine. When operating under normal conditions the 6,000-kilowatt turbo-generator requires 18 pounds of steam per kilowatt-hour, but when the steam consumption goes up to 19 pounds it is taken as an indication that scale has accumulated on the blades to an undesirable extent.

* Bulletin No. 3, Vol. XVIII. N. Y. Zoological Society. Reproduced by courtesy of the Society.

Bufor molitor, from South America.

Golden Tree toad of Australia.

How a Top Stands Up*

A Simple Explanation of a Frequently Recurring Phenomenon

By J. Swinburne, F.R.S., Past-President Institute of Electrical Engineers

If a mathematician is asked to explain the action of gyrostat, he generally says that the theory is to be und in Routh, or murmurs something about spins ing compounded like forces, which is rather like exlaining the action of an archdeacon by saying he exerses archidiaconal functions. The fundamental action a spinning body is susceptible of a quite simple planation.

Before dealing with the top, let us consider the modiation of the movement of a body, such, for instance, a rifle bullet, fired horizontally. The force of gravity ing at right angles to the direction of motion proces its own vertical component, independently of the ed of the bullet. The bullet has the same vertical otion as it would have had if it had no horizontal tion. If there were a stream of bullets from a axim, gravity would act on the stream so as to give same vertical acceleration independently of the rizontal velocity.

If a surface were put in front of the Maxim at a ght angle, so as to deflect the path of the bullets, y would exercise a great force on the surface norl to it. Thus, if the surface were curved through right angles, and were perfectly smooth, the stream bullets would be returned in the reverse direction at same velocity; and the pressure, which would be rmous, could be easily calculated from the frequency, d *vis viva*, of the bullets. A sort of Pelton wheel can imagined. If a perfectly efficient Pelton wheel has bucket held still, it returns the water at the same locity in the reverse direction.

Instead of considering a top as a rotating continuous g, it may be imagined as made up of a number of sses, each on the end of an arm. In the diagram rewith there are four little balls on arms with a cenl arbor, ending in a point at the lower end. This ns like a top; and adding more balls and arms until continuous felloe is obtained produces a top. Imagine top is spinning, and gravity is tending to make it ll so that ball *A*, which is at the lowest point, tends be moved still lower, and the ball *B* raised. Gravity ds to move these balls in directions at right angles their instantaneous direction of motion; so the balls er no resistance, due to their rapid motion.

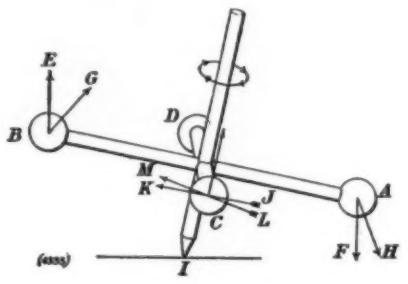
The arrows *E* and *F* show the direction of the pull of vity; and *G*, *H* the directions in which the balls ould be moved round the center *I*, at the point of the . Both *F* and *H* are at right angles to the direction motion of the ball. The ball *C*, however, is moving the direction *JK*, and if the top, as a whole, is moved und the axis through *CD*, or a parallel horizontal is through *I*, the path is altered toward such a direcn as *LM*. The ball will tend very strongly to go on ng its old path, and this will tend to bend its arm wn. Similarly, the ball *D* will tend to bend its arm . This will tend to tilt the top toward the observer; at is to say, in a direction at right angles to the vement the top would have had if it had not been inning.

If this movement begins, it alters the directions of vement of *A* and *B*, tending to make *A* move toward observer in a slightly downward direction, while *B* ves away at a slightly upward angle; but as this uld change the direction of movement, the balls *A* d *B* keeping their old courses, will tend to bend the m of *A* up and the arm of *B* down; that is to say, force of gravity will be counteracted by the force and down on *A* and *B* produced by the top as a hole leaning a little toward the observer.

The top will lean over just enough to counteract the ce of gravity at *A*, so that the lowest part of the top ll now be, not at *A*, but between *A* and *C*; and as s action continues, *C* will soon be the lowest point, d *A* and *B* will be level. The axis of the top will s describe a cone. The speed with which it deribes it will depend on the speed of the top; the ster it is spinning the greater is the force due to ange of direction of motion of each element.

The rim of the top may be considered as made up of ses like *A*, *B*, *C*, *D*, and elements of the rim that e between lowest and the medium, or medium and ghest positions, have partly translation movements at ght angles to the other directions of motion, which e rise to no forces tending to right the top, and ces due to change of direction.

If the top is spun in a slanting position, as shown, it s keeps itself up by precessing or preceding. "Pre-



ceding" sounds more like English, so scientific men prefer "precessing."

Returning to the diagram, if the top of the arbor is pushed toward the observer, it helps the precession; and the change of direction of the movement of *A* and *B* raises *A* and lowers *B;* and the arbor thus tends to move to the left. The arbor thus moves at right angles to the direction of the applied force. Helping the precession by external means thus raises the top to the vertical position.

The point *I* has been supposed to spin in the same place; but if the point is replaced by a small blunt nose, it will roll to some extent on the table; and in the diagram it will roll so that the point moves away from the observer. That tends to make *C* fall and *D* rise, and to alter the directions of motion of *A* and *B* in such a way that *A* is raised and *B* depressed. The point *I* will therefore run round as the top precedes; and its movement will gradually raise the top to a vertical position, so that it "sleeps."

The behavior of gyrostats under various conditions can be followed by seeing which parts of the spinning body have their directions of movement altered, and tracing the forces so produced.

This simple explanation was published about twenty years ago in *Good Words*. As it is possible that some of the members of the Institution did not see the number, it seems worth while to repeat it, as it may help the understanding of Prof. Gray's Kelvin Lecture.

Referring to the above explanation, which was reprinted in *Engineering*, Mr. G. Greenhill, a correspondent of the latter, sent the following comment:

I hasten to assure Mr. Swinburne we are very grateful for his eloquent explanation, in popular language, of why a top can keep upright against gravity pulling it down, giving us what Maxwell called "the gentlemanly knowledge of the subject no gentleman should be without."

We admire the popular explanation in words as much as a piece of amateur handicraft, in preference to the machine-made prosaic article of commerce.

Our gratitude takes the usual form of asking for more, so we should like a similar elegant discourse on the motion of the moon's Perigee, and why it is so rapid —4 degrees in a lunation, 40 degrees in a year, a revolution in nine years. Newton could account for only half of this amount; and it is on record that Clairaut, a hundred years later, was on the point of abandoning the law of gravitation in consequence, when he found the explanation was under his nose all the time, as the second term he was throwing away in his approximation was as large as the first term retained in Newton's method.

Newton reverses Mr. Swinburne's method in dealing with the motion of the moon, and the Regression of the node of her orbit. He smashes and shatters the moon into splinters, in a procession of small satellites, moving as if joined up together into a rigid ring; although stability requires the particles to be discreet as is a ring of Saturn, otherwise the ring would fall into contact with the central sphere. The disturbing effect of the sun he then assimilates to a hail of blows on these satellites, beating them back into the ecliptics in turn.

At first sight it would seem as if this treatment would end in hammering the moon's orbit flat into the ecliptic. But it does nothing of the kind, except to make the orbit flinch slightly and periodically in the variation of the inclination.

The chief permanent effect is to make the node regrede on the ecliptic, moving in a Regression, to meet the sun, like Precession.

To imitate this and the other top-like motion before a large audience, take an ordinary bicycle wheel with ball-bearings, and an axle prolonged both ways into a stalk. Spin the wheel with one end of the stalk in a cup, by hand, not with a string, and a top is realized on a large scale, visible at a distance.

Next take a stick of wood and hammer the rim, harder and harder, to see what happens. If the rim is hammered as the sun hammers the moon, beating it down at the highest point, the precession or progress is retarded, but the inclination of the axle is unaffected.

Try to beat the axle down by hammering it on the lowest point of the rim, and the precession is increased.

Similar action is carried out by the dynamical instinct of the bicyclist, only he must not stop on the road to think out the reason of every step.

Newton applied the same method to Precession, but not with the same success. For one thing, the astronomers gave him the weight of the moon double what we are told to-day, so he had to fudge his figures to make them agree with the facts.

Precessio Æquinoctiorum is the old Latin name in astronomy; in Greek, μετάπτωσις τῶν ἰσημεριῶν σημείων, so they must not be changed; but the verb "precess" is a modern Perry word.

In the discussion on the motion of the moon's Perigee, Newton used the analogy of the plummet in conical motion on a plumb line; but as he ignored the tangential component of the sun's disturbing force, he was only able to account for about half of the motion. But it turns out that the tangential component is of equal importance with the radial disturbing force. There is a popular explanation in Herschel's *Astronomy*, but it leaves us unconvinced, and here is where we ask Mr. Swinburne to come to our assistance in throwing this explanation into a better form, with the illustration of the conical pendulum at the same time.

When the mathematician murmurs a reference to Routh, he is sounding the questioner, to plumb the depth of his knowledge, so as to know where to begin the explanation, and what is the extent of previous knowledge he may assume; otherwise he will find he has expended much time and trouble only to be told—this is not the question.

The question in mathematics is the How much, rather than the How or Why.

For this last question the Kindergarten explanation in Perry's "Spinning Tops" is ample in general.

But the mathematician feels that, as in skating over thin ice, never stopping to look down, the novice can progress, whereas if he paused to consider the depth below, he would break through and go down, so the analytical difficulties in the theory of the top would drown the beginner if not kept out of sight as long as possible.

* From the *Journal* of the Institution of Electrical Engineers.

Nickel-Plating on Aluminium

A process for nickel-plating aluminium was recently described by MM. Canac and Tassilly to the Société d'Encouragement pour l'Industrie Nationale, as follows: The aluminium piece to be plated is passed first through a boiling potash bath, then brushed with milk of lime, dipped in a 0.2 per cent potassium cyanide bath for several minutes, and finally subjected to attack by an iron chloride solution—500 grammes hydrochloric acid, 500 grammes water, 2 grammes iron—till the appearance of the aluminium resembles crystallized tinplate. After each stage in this treatment the work is thoroughly washed in water. The following is found to be a satisfactory nickeling solution: Water, 1,000 cubic centimeters; nickel chloride, 50 grammes; boric acid, 20 grammes, worked at 2.5 volts and 1 ampere per square decimeter. The deposit obtained is matt-gray on leaving the bath, but easily takes a good polish under the scratch brush. Above all, it is claimed that the coating will stand bending and hammering without peeling or cracking. The reason for the adherence of the deposit appears to lie in the strong reducing action of the nascent hydrogen evolved when the aluminium is plunged in the ferric chloride pickle. Metallic iron is deposited on the aluminium, and, though its amount is so small—0.25 to 0.5 gramme per square meter—that it cannot form a continuous intermediate deposit, the iron forms with the aluminium a number of tiny couples favoring attack by the acid pickle. The surface of the aluminium is thus very minutely but very completely pitted, so that, besides being deposited on the nearest practicable approach to a chemically pure surface, the nickel coating is actually locked or "rooted" into every part of the aluminium surface, and it is on this mechanical action that the tenacity of the deposit depends.

Isostasy and Mountain Building*

How the Depressions and Eminences Upon the Earth's Surface Were Formed

By Luigi de Marchi

If we ignore the topographic irregularities of its surface, i. e., if we imagine it to be seen at a distance, as we see the moon, so that its mountains and valleys disappear, the earth has a precise geometrical figure, viz., that of a sphere flattened at the poles, or, to give it its geometrical name, an ellipsoid of revolution. It is the solid generated by the revolution of an ellipse about its minor axis. Although we cannot observe this fact with our eyes, we can determine it by means of geodetic and gravimetric measurements. These tell us—I need not here explain how—that if we imagine the mean surface of the sea, i. e., the surface resulting after the elimination of waves, the tide, and the inequalities due to variations in atmospheric pressure, prolonged through the continents in such a manner that it shall be everywhere horizontal, i. e., perpendicular to the plumb-line, on land as well as at sea, the resulting figure, which is called the *geoid*, will approximate in an extraordinary degree an ellipsoid of revolution. The maximum departure from this figure will amount, at the most, to only 100 meters, which is a very small fraction of the earth's radius.

Now, the form of the ellipsoid of revolution is the form assumed by a fluid mass rotating slowly about an axis, and is in all probability the form assumed by the terrestrial mass while it was still in a fluid state. That it still preserves this form is, however, remarkable, since it now certainly is, or at least behaves like, a rigid mass, with a rigidity comparable to that of steel, as shown by the precession of the equinoxes, oceanic and terrestrial tides, the propagation of seismic waves, etc. In other words, it is not a fluid body, but an elastic one.

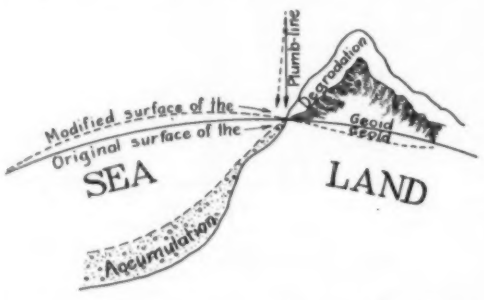
As such it must yield to the periodic action of the attractions of the heavenly bodies, and to the permanent and progressive action of all displacements of mass which may occur in its interior and on its surface. Of what happens in its interior we know nothing, but what happens at the surface lies beneath our eyes. Variations of temperature, frost, wind, the chemical and mechanical action of water, the beating of waves on the shore, all exercise a continual destructive action on the superficial rocks, which are thus disintegrated, fractured, pulverized; while running waters, the winds, and the action of gravity itself transport and distribute the products of demolition to places of lower level. The result toward which this geological process tends is the wearing away of elevations and the filling of depressions, i. e., the leveling of the terrestrial surface. This phenomenon does not, however, proceed in an equal and uniform manner over the whole surface, but is concentrated in certain definite zones. The zones where degradation is most intense are the mountainous and submountainous regions, which are most exposed to the effects of atmospheric agencies and to the erosion of torrential streams, and the coastal regions, subject to the constant erosion of the sea. The zones in which the accumulation of detritus is most rapid are the portions of the bottom of the ocean lying along the coasts of continents and islands, where the solid matter borne by rivers and eroded from the coasts by the waves is deposited, and inland regions of the continents where rivers which are unable to reach the sea or which flow sluggishly over the land deposit their alluvium.

Hence, we have zones where through whole geologic epochs a process of demolition and consequent lightening of the surface goes on, and zones where the opposite process goes on, i. e., accumulation and increasing weight. Briefly stated, the mountain masses are removed from their places and distributed over other parts of the earth's surface.

If the earth were absolutely rigid, to this continual transport of material there should correspond a progressive modification in the form of the geoid. The mobile mass of the oceanic waters would be more strongly attracted toward the regions where the transported material accumulates and ought to become heaped up over these regions, while the imaginary prolongation of the sea-level plane through the land, which, as we have said, must be considered as perpendicular at every point to the plumb-line, ought to become depressed beneath the regions of most rapid demolition, since the plumb-line would be deflected away from these regions toward the regions of accumulation. The accompanying figure represents this process schematically. Since this interchange of superficial mass continues through entire geological epochs, and always between the same regions, the deformation of the geoid should always proceed in the same direction, ultimately giving rise to marked changes from the initial form of an ellipsoid of revolution.

Instead of this being the case, the form of the geoid remains almost completely unchanged. This fact, positively ascertained, tells us that the earth does not behave like an absolutely rigid and indeformable body, but like an elastic body which adapts itself to the new distribution of superficial load; it yields under the weight of the materials heaped up in the regions of accumulation, which sink in proportion as accumulation progresses, and rises in the regions of degradation because these regions are progressively lightened. The rotation of the earth tends to restore the equilibrium from the geoid, i. e., the ellipsoid of revolution, from which the continual transport of superficial mass tends to cause the surface to deviate and to produce a sinking of the surface where the accumulation of material tends to raise it, and a rise of the surface where the process of degradation tends to lower it.

Several facts can be adduced in proof of these theoretical inductions. The great alluvial plains are covered with a mantle of fluvial deposits of such thickness that their base is sometimes several hundred meters below sea-level. Thus, wells bored in the valley of the



Po have yielded "terrestrial alluvium," with "terrestrial fossils," at more than 100 meters below the level of the sea. Evidently these deposits have sunk since they were laid down. Some of the great closed basins of the interior of Asia, where rivers lose themselves without finding an outlet to the sea, and where their detritus accumulates, are below the level of the sea, although surrounded by the loftiest mountain formations. The circumcontinental zones of the oceans, where the greatest amount of fluvial detritus accumulates, is also a zone of abysses of greatest depth.

In fact, if the ellipsoidal form of the geoid is to be preserved, it is necessary that the accumulation of detritus on the bottom of the sea shall have no effect upon the direction and force of gravity at the surface, and in order that this may be true the deepening must be greater than the thickness of the deposit, so that the effect of the increase in mass may be offset by that of an increase in distance from the surface. Naturally, this compensation will not be effected everywhere immediately, and hence arise the slight deformations which distinguish the geoid from the ellipsoid.

The permanence of the ellipsoidal form tells us that even during the continual mutations in the distribution of land and water which occurred during geological epochs, the sinking of the surface on the one hand and its elevation on the other must have been accompanied by such modifications in the underlying strata as to compensate the effects which such displacements would otherwise have had upon the distribution of gravity at the surface. Where a great basin was formed and filled with water, a stratum of lighter material (water) was substituted at the surface for a stratum of heavier material (rock), and thus there would have been a decrease in the force of gravity at the surface. With such variations there must have been a progressive and corresponding deformation of the geoid. If this has not occurred, i. e., if the distribution of gravity at the surface has continued to be very nearly what it would be on the surface of an ellipsoid of revolution, we must admit that beneath the oceanic abysses, while these were in course of formation, the material of the crust became denser, while at the same time beneath the continents in course of formation it became lighter. In other words, we must admit that beneath the seas there is "excess of mass" and beneath the continents "deficiency of mass," which compensate, respectively, in the gravimetric effect on a pendulum at the surface, the deficiency and excess of superficial mass; i. e., the material of the crust is more compressed under the than under the continents. It is recognized, how that these anomalies are limited to a superficial tum, calculated to have a depth of about 112 meters, beneath which we enter a region of uniform regularly increasing density. Hence, the super layer of irregular density presses down with uni weight upon the underlying nucleus, in which longer felt the effects of the irregular distributio land and water. It will, therefore, be in equilib (Greek *isostasis*), and hence this conception of structure of the globe is called the *isostatic theory*.

This compensation in the distribution of surface subterranean mass which occurs on a large scal oceanic and continental areas also occurs, though erally in a less perfect degree, in the areas occupie mountains and plains. Measures of gravity prove beneath the mountains there is a deficiency of m i. e., that, as the great mountain masses rose, the material of which they are composed and which beneath them expanded and diminished in density. is natural, if we admit that the elevation of moun occurred in regions where the lightening of the su crust proceeded most actively under the eroding ence of atmospheric agencies and running waters, material thus relieved of weight expanding as it to

The mathematical theory of elasticity confirms these results, proving that where the surface of earth sinks, forming a depression, the underlying ma rial is condensed to such an extent that, if the de sion fills with water, the force of gravity at the sur remains as it was before; where the surface rises, fo ing a mountain range, the material underneath expa but in this case the force of gravity is not compens and it feels the effect (much attenuated, however, the expansion of the material) of the mountain ma

The same theory tells us, moreover, what forces what movements are brought into play in the ea crust under the effect of these vertical displacem not to speak of elastic forces, a subject too comple discuss here, suffice it to say that in the strata u the surface there is a flow of material from the upli and lightened areas to the depressed and heavily lo areas, while at a depth of many miles there is a In the opposite direction, from the depressed to the lifted regions. These two horizontal movements, c bined with the vertical movements of ascent under light regions and descent under the heavy regions, c stitute a species of rotation of mass. Under the ef of this movement the sediments which are depos and at the same time carried downward, producin basin-like deformation in the subjacent rocks—a *geo cline*, as geologists say—are pushed, along with the derlying rocks, at a great depth under the regions diminished pressure. As observation tells us that process occurs principally along the coastal zones. cause the great mountains of most recent formati border the seas and adjoin the great oceanic and m terranean depressions, we may say that under th circumstances the sediments collected in the geo clines are pushed under the continents from wh they came. It will be seen that, under this c tinued pressure, their arrangement, originally regu may become profoundly distorted, producing ri fractures, flows, etc. These dislocations occur at great depth, under the pressure of the superinco bent strata, and where the high temperature gives the material great plasticity. Indeed, it is not i missible that such grandiose and profound con sions as are seen in the structure of the superfi strata could have been produced while these strata w at the surface; for in that case, the strata would ha been completely broken to pieces, whereas they actu present in their most colossal and most minute folds. some cases rolled over one another through distances tens and hundreds of kilometers, an extraordinary c tinuity.

The strata, acquiring a movement of ascent beneath the light regions of the crust, would return, grad dislocated, to the surface of the continents. Their e vation would have the character of slow and wi spread bradyseismal movements, and under the acti of atmospheric agents and the water-courses produ by the rising of the land, valleys would be carved revealing the distorted structure of the crust, as i duced far down in the earth.

Such, in its broader lines, is the theory upon wh setting out from the principle of terrestrial isostasy,

* Translated for the SCIENTIFIC AMERICAN SUPPLEMENT from *La Geografia*.

try to explain the formation of the depressions and eminences which, through incessant vicissitudes, deform and reshape the surface of the globe.

I should have to exceed the limits of a brief popular article to set forth in detail the geological facts which give support to this theory, such, for example, as the direction of folding of the strata and the distribution of volcanoes, or to mention the objections which it has to meet. I shall content myself with having given a general idea of a theory which is still in its infancy, but which, in my opinion, contains a more substantial nucleus of truth than any of the many other attempts heretofore made to explain the principal lineaments of the earth's surface.

[Further information concerning the isostatic hypothesis will be found in Mr. Bailey Willis's article "What is Terra Firma?" in the SCIENTIFIC AMERICAN SUPPLEMENT, May 4th, 1912.—EDITOR.]

Imitation Precious Stones

The present state of war in Europe has resulted in an appreciable scarcity of imitation precious stones in every market, for, not only has the prosecution of the industry, which is largely confined to Bohemia, been interrupted, but the distribution of the finished product, by land and sea, has been brought to a standstill. This condition has extended to the United States, and a leading firm, engaged in the importation of these goods, experienced difficulty in filling an unusually large order for special artificial stones of large size for the Tower of Jewels, that forms a conspicuous part of the Panama-San Francisco Exposition, and in which artificial stones constitute the chief decorative feature.

This has served to direct special attention to the industry, and efforts are being made to produce the article in this country, at the present time. Therefore the following information and receipts in regard to the production of these stones, for cheap jewelry, etc., recently published in the *Deutsche Goldschimede Zeitung*, is likely to prove of more than passing interest.

If precious stones are to be imitated, in which the first consideration is clarity and beauty, the crucible must first be subjected to a special preparation. Ordinary glass is crushed to powder, the inside of the crucible is wetted with water and it is then shaken about so that the crushed glass adheres uniformly, the surplus being then poured out. The crucible thus treated is then slowly dried, it is then placed in a fire hot enough to melt the adherent glass. The fire is kept up for a time, finally allowed to die out, and the crucible, without being removed, allowed to cool gradually.

A crucible thus prepared and two thirds filled with the composition, is set on a support in the smelting furnace, and in order to prevent anything falling in, which would contaminate the contents, is covered with a lid that projects over the edge of the crucible. Then, for the first hour, or even longer, a moderate fire is kept up, in which the crucible attains only a red heat. After this period, the fire is gradually raised until the crucible attains a white heat, and the material it contains is melted. If arsenic is contained in the composition, a hotter fire must be kept up from the start, as it is easily vaporized. When the material melts we take from time to time a little from the top of the contents on a small gypsum rod, to ascertain whether it has been completely transformed into glass.

In the meantime, great care must be taken that the crucible, as long as it remains in the fire, is not moved nor jarred, and above all that its contents are not stirred, otherwise bubbles will easily be formed in the glass. If, on taking out a sample, bubbles are seen to be present, the glass must be kept long enough in a fluid condition to permit them to disappear. If, after the lapse of some time, they have not disappeared, a hotter fire must be made up, so that the glass is reduced to a thinner fluidity.

When the sample shows that the vitrifaction is complete, the fire is slackened and gradually allowed to go out, the crucible being allowed to remain in the furnace until everything has had time to gradually cool off spontaneously, and the glass is then removed from the crucible. The crucible may also be removed at once from the fire; the liquid glass poured on to a clean copper or iron plate, and as desired, pressed flat for future use. While it is still hot, it must, however, be replaced in a furnace, and exposed for an hour to the heat of a moderate fire, which is then allowed to die out—for the more slowly glass is cooled the harder and more durable it will be.

A glass melt of 10 to 11 pounds requires, for its complete vitrifaction, 20 to 24 hours firing. For smaller quantities the firing period is, of course, shorter. The glass, however, improves the longer it is kept in a fluid condition. If, however, the glass is to be only semi-transparent, or if arsenic enters into its composition, the fire must be kept up only as long as is necessary for vitrifaction; a longer period would render the glass transparent.

Following are some compositions for the preparation of imitations of diamonds:

(1). 100 parts of white sand washed first in hydrochloric acid and then in water, 150 parts minium, 30 to 35 parts of good calcined potash, 10 parts calcined borax, 1 part dioxide of arsenic.

(2). 100 parts of white sand, washed in hydrochloric acid and then in water, 40 parts minium, 24 parts white, well-calcined potash, 20 parts calcined borax, 12 parts nitrate of potash, 0.4 part of peroxide of manganese.

(3). 100 parts of white sand, washed in hydrochloric acid, and then in water, 140 parts minium, 32 parts well-calcined potash, 12 parts calcined borax, 0.6 part dioxide of arsenic.

(4). 62.50 grammes (parts by weight) of calcined silica, 31.25 grammes (parts) of pure potash, 10 grammes (parts) of calcined borax, 3 grammes (parts) of good white lead. The silica must be pulverized, sifted and then mixed with all the other ingredients enumerated, which have been melted over a hot fire. If the operation is to succeed, a crucible must be used of which nothing will combine with the melted composition, and in which the ingredients can be kept for 10 hours in a melted condition.

A few combinations of paste that can be used for the imitation of colored precious stones are as follows:

(1). 25 parts white sand, washed in hydrochloric acid and then in water, 50 parts minium, 7 parts first quality calcined potash, 8 parts crystallized nitrate of potash.

(2). 25 parts white sand, washed in hydrochloric acid and then in water, 60 parts minium, 4 parts fine calcined potash, 6 parts calcined borax, 0.15 parts dioxide of arsenic, 0.10 parts peroxide of manganese.

(3). 25 parts of white sand, washed in hydrochloric acid and then in water, 55 parts minium, 10 parts first quality calcined potash, 8 parts calcined borax, 5 parts crystallized nitrate of potash.

These various mixtures must be melted in good crucibles, that are not only very difficult of fusion, but which will also not be attacked by the different substances. If we are only preparing small quantities of paste, we can make small crucibles for the purpose from pure alumina, which can be precipitated from alum by any potash salt. The products obtained in such a crucible are very transparent, and have a fine white color. They must be kept uninterruptedly in a fluid condition for two or three days, on the one hand to remove the excess of alkali and on the other, to purify them. If, however, the operation is conducted on a small scale and in a good melting furnace, a period of 10 to 12 hours will suffice.

Composition for the production of an *aqua-marine colored* glass paste: 187.50 grammes of paste; 1.50 grammes of antimony; 0.09 grammes oxide of cobalt.

Amethyst colored glass paste: 10 parts white sand, washed in hydrochloric acid and then in water, 15 parts minium, 3 parts first quality calcined potash, 2 parts calcined borax, 1 part peroxide of manganese, 0.10 part Cassius powder.

Emerald green glass paste: (1) 31.25 grammes (parts by weight) paste, 0.24 gramme (part) oxide of copper, precipitated from fine nitrate by means of potash.

(2). 10 parts of white sand, washed in hydrochloric acid and in water, 15 parts minium, 3 parts white calcined potash, 2 parts calcined borax, 0.5 part of yellow oxide of antimony, 0.1 part of pure oxide of cobalt.

(3). 10 parts of white sand, washed in hydrochloric acid and in water, 15 parts minium, 5 parts calcined potash, 2 parts calcined borax, 0.25 part of green chromic oxide.

The shades of color can be varied greatly by increasing or diminishing the addition of coloring oxides.

Hyacinth colored glass paste:—31.25 grammes (parts by weight) of paste, 1.44 gramme (part) dioxide of iron. Both substances are melted together in the crucible. By increasing the addition of iron oxide the shade of color may be changed from red to chestnut brown.

Garnet colored glass paste:—The process is the same as described for the artificial hyacinth, except that the proportion of dioxide of iron must be somewhat increased. Another composition which is really preferable to the former process, is the following: 31.25 grammes (parts) of paste, 0.12 gramme (part) of cassius powder.

Opalescent glass paste:—25 parts of white sand, washed in hydrochloric acid and then in water, 20 parts minium, 10 parts calcined potash, 2 parts crystallized nitrate of potash, 16 parts white oxide of tin.

Ruby-colored glass paste:—(1). 8 parts paste, 1 part dark topaz. This composition yields a very fine ruby.

(2). 31.25 grammes (parts by weight) paste, 0.18 gramme (part) cassius powder.

Sapphire-colored glass paste:—(1). 31.25 grammes (parts in weight) of paste, 0.12 gramme (part) oxide of cobalt precipitated from fine nitrate by means of potash.

(3). 10 parts of white sand, well washed in hydrochloric acid and then in water, 15 parts minium, 3 parts calcined potash, 1 part borax, 1 part crystallized nitrate of potash, 0.18 part of a very fine oxide of cobalt.

Topaz-colored glass paste:—(1). 41.25 grammes (parts in weight) of paste, 2.58 grammes (parts in weight) of antimony, 0.06 gramme (part) cassius powder. If the melting process has not been rightly conducted, the product will be dark colored and can then only be used for the preparation of artificial rubies.

(2). 100 parts white sand, washed in hydrochloric acid and then in water, 145 parts minium, 32 parts calcined potash, 9 parts calcined borax, 5 parts oxide of silver.

The production of imitation gems in Bohemia is, of course, carried out on a large scale with factory methods, the stones being roughly shaped in suitable moulds and then mechanically cut and polished.

Drilling for Oil

Improved Engineering Methods

IN a paper on "Boring and Drilling on Oilfields" before the Institution of Mining Engineers, Dr. Paul Dvorkovitz discussed the methods employed and referred to the improvements that have been effected in the plant.

He remarked that drilling for oil is essentially an engineering work, and one fraught with numerous engineering difficulties. Great improvements have been made in connection with the methods adopted since the time when, in the early days of the petroleum industry in Rumania, the sole method of securing oil in the Bustenari region was by means of hand-dug shafts, until now when shafts for oil are quickly sunk 4,000 feet, and even 5,000 feet, into the earth. But all engineering work in connection with deep drilling must needs be unsuccessful if the necessary competent labor to superintend the operations is wanting. This shortage has for many years been the one stumbling block to real progress in the commercial development of oilfields. Now, however, there is growing up a miniature army of engineers who in time will prove of enormous value to the world's petroleum industry, by reason of their studies of the practical side of oilfield development.

After describing the principal types of percussion drills used in oilfield work—the Pennsylvanian cable, the Canadian pole, and the Russian free-fall—the author referred to the hydraulic rotary drill system, which he regards as one of the most important innovations yet introduced in connection with oil wells. Manufactured on a commercial scale in the United States, but now designed and marketed by British makers, it has completely revolutionized the drilling of oil wells in every part of the world, and even in Russia, where there is open opposition to every new system, it is making a name for itself. Introduced into the Texas and Louisiana oilfields about twelve years ago, it met with remarkable success, and over 20,000 wells have been drilled by its aid in the United States. With the old percussion methods drilling at the best must be very slow, but with the rotary system the drilling of over 100 feet a day has frequently been accomplished in favorable territory.

In the rotary system the hole is made by the constant rotation of the bit on the formations, the loosened material being washed from the well by a continuous stream of water forced down the drill-stem under pressure. The utilization of a mud-flush is a distinct improvement in the efficiency of the method; all loose formation is held back, and caving-in prevented by the pressure of a column of mud of varying consistency (according to the nature of the formation being passed through), which is pumped down the well through the drill-pipe, and circulates from the bottom of the hole round the drill-stem to the surface, thereby plastering the walls of the well. The mud emerges in streams of high velocity from two holes in the drilling bit, strikes against the formations being drilled, and on its return to the surface carries with it the cuttings which, owing to the reduced velocity, are deposited in the mud-trough during the course of the mud from the flow-line back to the pump.

Objections have been raised to the rotary system in general on the ground that it does not enable an accurate log of the strata passed through to be obtained; but in the mud-flush system the time required for the stream of mud to carry the pieces of formation from the bottom of the well to the surface is only a few minutes, and therefore the driller can be constantly informed of the nature of the strata.—*London Times.*

Photographic Maps*

Methods of Producing Correct Charts With the Camera

MANY photographs taken from airships give beautiful views, rich in detail, of the landscape beneath. If such a photograph is compared with a large-scale map of the same region little difference is observed in the relative positions of buildings and other prominent objects, and if we know that a bridge shown in the photograph is 200 yards long we may safely infer that two houses, which the photograph shows separated by an interval equal to twice the length of the bridge, are in reality about 400 yards apart.

Then we recall seeing old town maps, called "bird's-eye views," which represented buildings and other features in a manner not unlike that of the photograph, so that their character was evident even to an unpractised eye. In modern topographical maps such features are indicated by conventional signs, which often mean nothing except to an expert.

The method of the old town maps was probably abandoned because the increased area and complexity of towns made it impossible to draw pictorial representations of all of their features on a map of tolerable size. But a correct representation of the finest details can be produced by photography.

The photographic map has been evolved from the balloon photograph by means of several devices, invented by the late Capt. Th. Scheimplug of the Austrian army.

In photographing a painting, the axis of the camera should be directed perpendicularly to the canvas, near its center, and the planes of the canvas and the photographic plate should be parallel. Neglect of these precautions produces distortion. For the same reason, the axis of the balloon camera should be as nearly vertical and the plate as nearly horizontal as possible.

In order to photograph an extensive region from an airship with an ordinary camera it would be necessary to combine a number of views taken at short inter... but only a narrow strip in the middle of the combi... picture would be free from distortion. Furtherm... some objects at the side of the field would be conceal... by other objects and, consequently, would not appe... in the photograph. For example, the small lateral e... tension of the house on the left, in Fig. 1, does not a... pear on the plate, because it lies inside a line dra... from the eaves to the lens. A similar extension ... either side of the other house, which is directly un... the lens, would show in the photograph. Hence, ... order to produce a satisfactory view of a wide belt ... territory it would be necessary to combine seve... narrow strips obtained by flying in as many paral... courses—a very difficult thing to do, especially o... hostile territory.

These considerations led to the invention of t... Scheimpflug multiple camera (Figs. 2 and 3). In t...

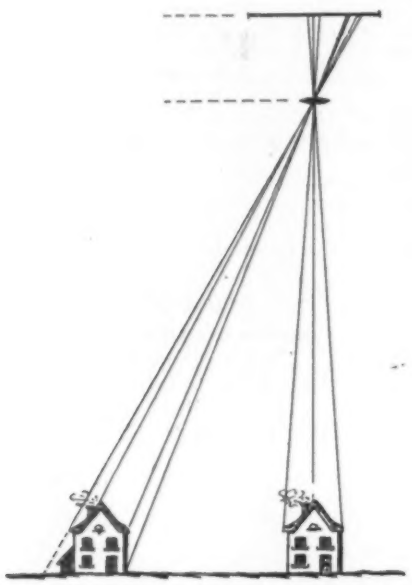


Fig. 1.—How objects at the side of the field are masked by other objects.

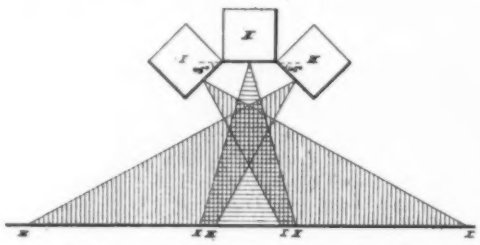


Fig. 4.—Overlapping fields of central and lateral cameras.

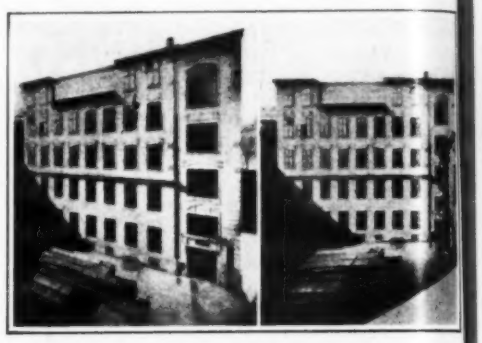


Fig. 7.—An oblique photograph rectified.

* Abstract of City Surveyor Kappel's article in *Die Umschau.*

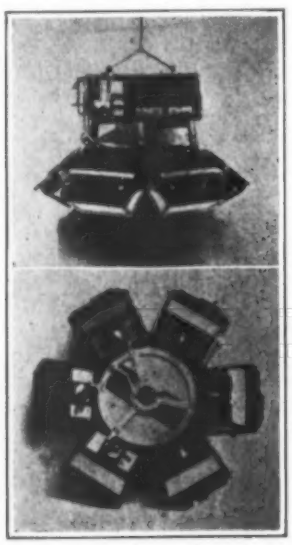


Fig. 2.—The Schiempflug multiple camera (side and bottom views).

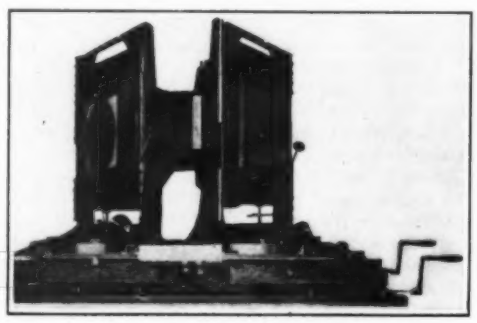


Fig. 5.—The rectifying camera.

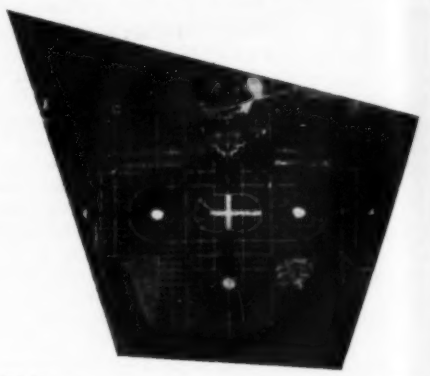


Fig. 8.—Photograph of a cemetery viewed obliquely from a balloon.

Fig. 9.—The oblique view (Fig. 8), corrected by use of the rectifying camera.

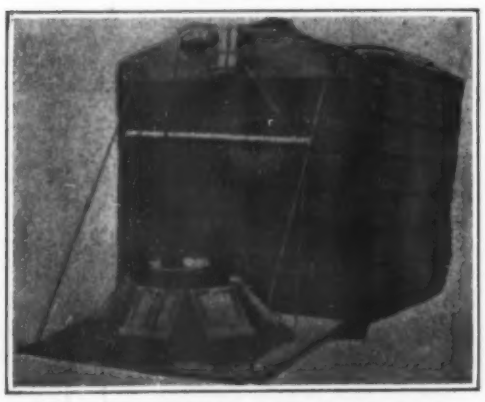


Fig. 3.—The multiple camera attached to the balloon car.

Fig. 6.—A correct photograph distorted by the rectifying camera.

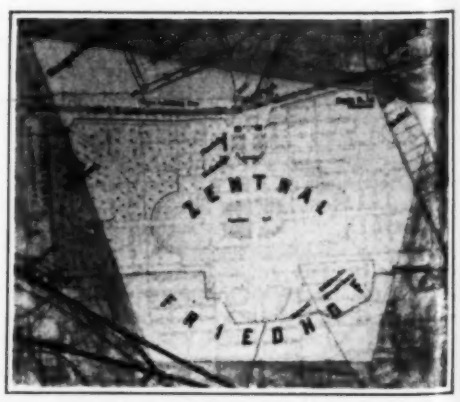


Fig. 10.—Official map of district shown in Figs. 8 and 9.

apparatus a central camera with its plate horizontal is surrounded by six other cameras, having their plates inclined symmetrically toward the central plate. The increased width of field obtained by this arrangement is illustrated in Fig. 4. The width of field of the central camera is the distance II-II on the base line, while the total field of the three cameras extends from III on the extreme left of the drawing to I on the extreme right.

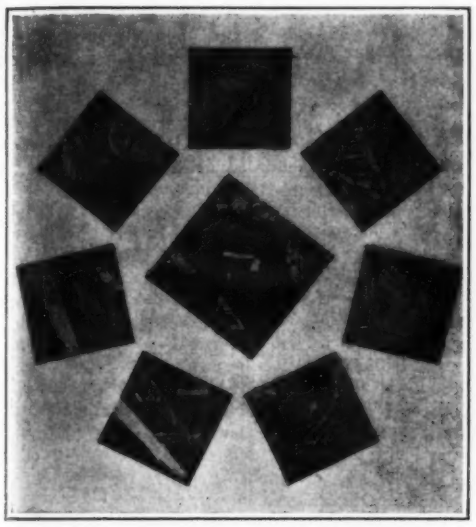


Fig. 11.—A group of negatives made simultaneously with the multiple camera.

Fig. 12.—The oblique views rectified and combined with the central picture.

The inclined cameras necessarily produce distortion, but this is removed by copying the plates in the Scheimpflug rectifying camera (Fig. 5), which is a copying camera so contrived that the picture to be copied and the sensitive plate can be inclined to each other at any desired angle. In this camera a correct photograph produces a distorted copy (Fig. 6), and, conversely, a rectified copy can be made from a distorted photograph, by reversing the obliquity that caused the distortion. In this way the rectified photograph on the right side of Fig. 7 was obtained from the distorted photograph on the left. Fig. 8 shows an obliquely taken balloon photograph of rectangular cemetery plots. The rectifying camera transformed this into Fig. 9, which agrees closely with the official cemetery map (Fig. 10).

Fig. 11 shows a group of negatives made simultaneously with a Scheimpflug multiple camera (octuple in this instance). The seven outlying and inclined views were rectified and combined with the central picture, with the result shown in Fig. 12, which agrees very well with the government map (Fig. 14). One of the rectified partial views is reproduced separately in Fig. 13.

It is not necessary to follow in detail the method by which the pictures are combined in order to understand that such combination is possible, and that it can be made with substantial accuracy by bringing into coincidence corresponding points of adjacent pictures, the fields of which always overlap, as Fig. 4 and Fig. 11 show. If greater accuracy is desired, conspicuous beacons may be placed, before the photographs are taken, at suitable points of the landscape, the relative positions of which are accurately known.

If a symmetrical mountain peak or other similar object is photographed obliquely, its two flanks occupy unequal areas in the photograph (Fig. 15). Scheimpflug has devised special apparatus for the elimination of this disproportion, which is not corrected by the rectifying camera described above.

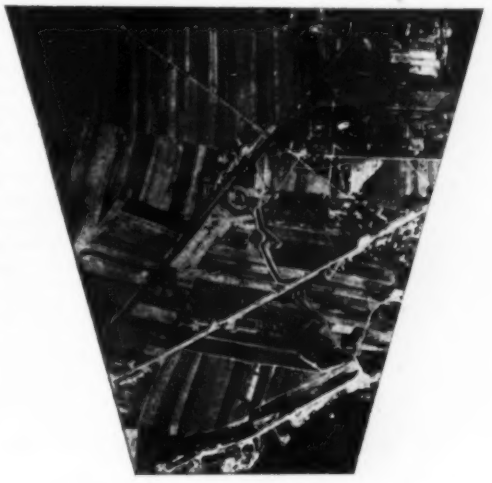


Fig. 13.—One of the inclined views rectified.

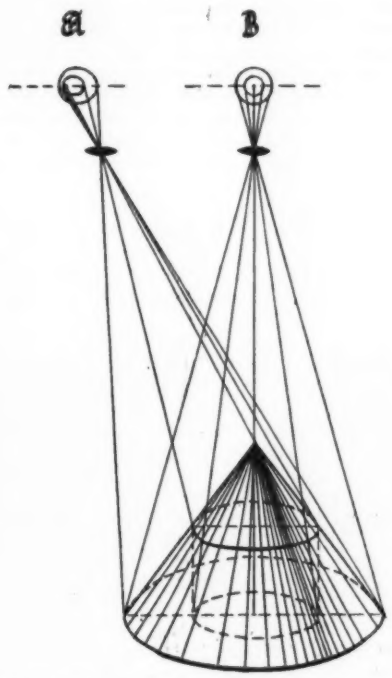


Fig. 15.—Disproportion between opposite flanks of a mountain photographed obliquely.

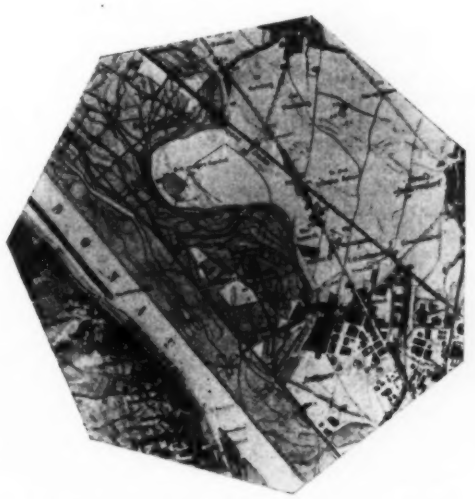


Fig. 14.—Map of the region photographed in Figs. 11 and 12.

Magnetization by Rotation*

About six years ago I published in this journal a note in which it was shown that on the modern theory of magnetism any magnetic substance should become magnetized by a sort of molecular gyroscopic process on being set into rotation. Rotation should produce in any substance an intrinsic magnetic intensity parallel to the axis of rotation, proportional to the angular velocity, and (like the magnetization of the earth) directed oppositely to the magnetic intensity which would be produced by an electric current circulating around the substance in the direction of rotation. If the rotating body is magnetic, magnetization, proportional to the intensity, should result; otherwise not (except to a very minute extent).

Preliminary experiments mentioned in the note referred to appeared, though doubtfully, to show the effect in question in the case of a large iron rod rotated at a speed of about 90 revolutions per second. Later observations made in much the same way, but with an attempt at improvement in the apparatus, failed to confirm this result with any certainty; and further investigation was postponed until better facilities were available.

Recently I have made, again with Mrs. Barnett's assistance, experiments which have yielded definite and conclusive results. In the final experiments two nearly similar rods of steel shafting were mounted with their axes horizontal and perpendicular to the magnetic meridian, and two similar coils of insulated wire were mounted about their centers. These coils were connected in series with one another and with a Grassot fluxmeter, and were oppositely wound so that any variations in the intensity of the earth's field produced no effect on the fluxmeter. One of the rods remained at rest; while the other, mounted in a region in which the earth's magnetic intensity was compensated by an electric current flowing in a very large coil, was alternately rotated by an air motor and brought to rest, the change of flux for different speeds and different directions of rotation being determined by the fluxmeter. The fluxmeter was compensated for extraneous electromotive forces, and was read by mirror and scale to 0.1 millimeter at the scale distance 8 meters. After all suspected sources of systematic error were eliminated, an effect was left corresponding precisely with that predicted by the above theory and inexplicable on any other theory hitherto proposed. The intrinsic magnetic intensity of rotation per unit speed, and the change of flux-density at the center of the iron rod per unit speed, were found to be 3.1×10^{-7} gauss/revolutions per second and 1.9×10^{-5} maxwells/centimeters^2 per revolutions per second, respectively.

From experiments made for a different purpose by Lebedew in 1912, it can be shown that in non-magnetic substances not more than a minute fraction of the magnetization we have observed in iron is produced at the same speed.

It is not, of course, possible to obtain iron rods entirely free from magnetization, and observations were always made on changes of residual flux. Together with the change of flux proportional to the angular velocity, the effect being looked for, another change, proportional to the square of the angular velocity, was found and traced to the radial expansion of the rod produced by rotation.

The intensity of magnetization per unit speed produced at the center of the iron rod was about 1.5×10^{-6} centimeters grammes seconds unit per revolutions per second. If the rod had been rotated at the speed of the earth, viz., 1/86,400 revolutions per second, its intensity of magnetization would have been about 2×10^{-10} that of the earth, and still less if the shape had been spherical. This, however, does not prove that even a very large part of the earth's magnetization may not be due to the effect in question, as we are entirely ignorant of the magnetic properties of all substances under the conditions prevailing within almost the whole of the earth. Schuster has pointed out that an effect of this kind may explain both the mean magnetization of the earth and the secular variation as well. It seems more likely, however, that a large part of terrestrial and solar magnetization is due to other causes, such as the outward radial displacement of electrons by centrifugal and thermionic action.

A full account of the work summarized here, and presented to the American Physical Society at its meetings of last December and April, will be published in the *Physical Review*. .

By S. J. Barnett, of the Ohio State University, in *Science*.

A Three Hundred Dollar Automobile a Reality.—Listed to be sold at $300, a new four-cylinder, air-cooled, friction-drive automobile is announced. The designer is Charles E. Duryea, the well-known pioneer of the early automobile days in this country. The car is to be ready in time for the automobile show in New York.

Control and Protection of Electric Systems*

Problems That Have Arisen With Increase of Power and Extension of Circuits

By Charles P. Steinmetz†

When the first commerical electric circuit issued from a station, the problem of control and of protection arose. It was a simple problem at first—an ammeter and voltmeter to measure current and voltage; a knife-blade switch to send the current into the desired path or withdraw it; the fuse to open the circuit in emergencies, and, if the wires became crossed and the fuse and switch failed, the generator and engines stopped, and not much harm was done. With the extension of the circuits into the suburbs, some lightning troubles were felt, which led to the introduction of lightning arresters.

Since those days, less than a generation ago, enormous changes have taken place, and the electric systems have increased in size, in voltage, and in extension. Where 100-horse-power machines were large once, now turbo-alternators of over 40,000-horse-power are in commercial operation. The steam engine has made room for the steam turbine, and the steam turbine does not stop when the wires are crossed and a short-circuit occurs; the momentum of the turbine disks, revolving at velocities of 300 to 400 miles per hour, can supply ample energy for the destruction of any part of the system. Attempts to open such circuits by the knife-blade switch of old would lead to the destruction of the switch, and probably its operator.

Instead of small machines operating separately on independent circuits, huge generators now feed in parallel into the system of busbars, on which is concentrated all the power of the station or the group of stations tied together. Numerous stations and systems of interconnected stations of 100,000 to a quarter-million horse-power and over are in operation, and the half-million horse-power mark has been reached.

Anywhere on the busbars of the station or in the feeders near the station there is available, destructively in case of an accident, as a short-circuit, not only the entire power of the station, but the far greater power which the station generators can give momentarily. Short-circuit currents of forty to fifty times normal full-load current may momentarily flow from some turbo-alternators, representing ten and more times full-load power. Such a station, or group of closely interconnected stations, of half a million horse-power full-load capacity, may momentarily send into a short-circuit at the busbars over five million horse-power. This is the power of Niagara, which is estimated variously at from 5,000,000 to 15,000,000 horse-power. It is obvious that no switch or circuit-breaker can be built to safely relieve such power.

With half a million horse-power station capacity, a momentary overload capacity ten times as high, assuming that we could build a circuit-breaker to open this short-circuit power as quickly as in three to four cycles, or one-eighth second, would require dissipating in the circuit-breaker the energy of over 200,000,000 foot-pound—the destructive energy of 1,000 tons dropping from a height of 100 feet, that of a projectile weighing 2,000 pounds, leaving the cannon at a velocity of 2,500 feet per second, or the destructive energy of two heavy railway trains, going at sixty miles per hour, and meeting head-on.

Equally great has been the increase of voltage. Where once 2,000 volts was high, in circuits of a few miles in length, now circuits of over 200 miles are in operation at 100,000 to 150,000 volts. Current at such voltages jumps toward an object over a foot distant, and will maintain arcs of practically unlimited distance; that is, with 100,000 volts and almost unlimited power back of it, an arc can extend for several hundred feet. Thus, no simple switch will open a circuit at such voltages under power.

Lightning protection also has become a far larger problem than in the small circuits of old. But far greater than the energy of any lightning stroke is the energy stored as magnetic field surrounding the conductors and as dielectric field radiating from the conductors of these big transmission systems, and, if this internal energy of the system is set surging, its effects are far more destructive than those of lightning. The effects may not be merely momentary, as those of lightning, but continual, as machine energy keeps replacing the stored internal energy, which causes the destructive surge. The foremost problem of control of electric systems thus is that of controlling enormous powers; the foremost problem of protection is that against self-destruction by its own power.

Current and voltage have grown beyond the values for which instruments can be built, and current transformers and voltmeter transformers are interposed between the circuit and the instruments measuring it. With the general introduction of parallel operation, power-factor indicators are required to insure the division of load without excessive waste currents; and frequency indicators and synchronizing devices to safely connect machines into the system.

With hundreds of feeders radiating from the generating station, the office of the load dispatcher has become essential, and the necessity of keeping exact records of all operations and of all accidents and incidents is of the greatest importance. Automatic recording devices thus have been developed, as the multi-recorder, to record within fractional seconds all important events—opening and closing of switches, starting and stopping of generators, surges, lightning disturbances, etc. Such automatic devices afford a valuable check on the operating staff, but more important still is their record in emergencies. Where a number of things happen almost at once and the attention of the operator is distracted from accurate observation by the necessity of action, the record thus could be made only afterward from memory. It is just in such abnormal conditions where the most complete and accurate record is of greatest importance, to enable the engineers to determine with certainty what happened and why it happened, so as to take steps to guard against its recurrence.

Oil circuit-breakers have been developed, which can safely and without disturbance close and open feeder circuits of over 10,000-horse-power and generator circuits of 40,000 horse-power. In these the circuit is opened under oil so that at the instant of opening, the current is extinguished at the end of a half-wave by the rapid expansion and chilling of the oil vapor produced by the opening arc; this at first is under high compression, due to the momentum of the oil which has to be set in motion.

The possibility of self-destruction by the power let loose under short-circuit was solved by the development of the power-limiting reactances. In the generator leads, between generators and busbars, are inserted reactances capable of withstanding enormous overloads, but of a size sufficiently small not to interfere with the normal flow of power at full load or any overload that the generator may be called upon to carry. They are large enough, however, to materially limit the generator current and power on short-circuit. Usually the generator reactances limit the momentary short-circuit current to about ten to twelve times full-load current; that is, the momentary short-circuit power to about two and one half times full-load power. This solved the problem for medium-sized stations.

However, even with generator reactances, with the increasing size of station, the power that may be let loose under short-circuit becomes large beyond control, and busbar reactances were next introduced. By such reactances in the busbars and in the tie feeders between the stations, the system is divided into sections of about 60,000 horse-power each. A short-circuit then can seriously involve one busbar section only.

With hundreds of feeders radiating from the busbars, the probability of a short-circuit in the feeders is far greater than in the busbars, and a material advantage, therefore, is given by feeder reactances.

By the development of generator reactances, busbar reactances, and feeder reactance the problem of the power control of large systems for protection against self-destruction by short-circuit has been solved and unlimited extension of systems without any increase of danger has been made possible; and experience has shown that after the introduction of such power-limiting reactances, dead short-circuits have occurred at the busbars of very large systems without even interfering with the operation of most of the synchronous apparatus on the system.

The two main sources of trouble in lines and cables are grounds and short-circuits between phases. In transmission lines a ground on one phase is the most frequent trouble, and short-circuits are rare except in lines in which the design is faulty or reliability has been sacrificed to cheapness. A short-circuit is far more serious than a ground, as in the former the current is limited by the generator capacity, while with a ground the current has no return unless the neutral is grounded, and then over the resistance of the neutral. In a well-designed transmission line, a short-circuit usually occurs only as the result of two simultaneous grounds. A ground on one conductor, however, raises the voltage to ground of the other two phases, from the Y voltage to the delta voltage of the system, and thereby increases the strain on the insulation of the other two phases. It thus introduces the danger of a second ground, causing a short-circuit, or requires higher insulation.

This has led to two methods of operation of transmission systems. In the first, the neutral of the transformers is grounded, frequently through a resistance, where the resistance of the ground is not high enough to limit the current. Then a ground on one phase is a partial short-circuit to the neutral, causing a large current to flow, and thereby opening the circuit-breakers before the ground has developed into a short-circuit. However, this method, the grounded Y system, means a shutdown at every ground, every flashover of an insulator by lightning, etc. In the second method, the neutral is not grounded, but the insulation of the circuit is good enough to safely stand the increased strain put on it by a ground on one phase, and by means of an arcing ground suppressor, etc., care is taken not to continue the arcing ground, leading to high-frequency disturbances, but convert it into a metallic ground. In this case, the "isolated delta" system can be maintained in service, even if one phase grounds, until arrangements are made to take care of the load or the fault is found and remedied. However, the cost of line construction is higher, because of the better insulation required. The relation between grounded Y and isolated delta is one of cheapness versus reliability and continuity of operation.

Different are the conditions in underground cable systems. In a cable, the three conductors are so close together that a ground on one conductor quickly reaches the others and becomes a short-circuit. A grounded cable, therefore, cannot be kept in service, but has to be cut out promptly. In these systems it is customary to ground the neutral through a resistance sufficiently low, in case of a ground on one conductor of a cable, to allow enough current to flow to open the circuit-breaker and cut off the cable, but not sufficient to give a severe shock to the system. Or, where grounding of the neutral is considered undesirable, an arrangement of relays is made to give the same effect. With underground cables such cutting off of a disabled feeder does not interfere with the continuity of service, as a number of feeder cables are always used in multiple for every important substation.

However, the problem of cutting off a disabled feeder by the operation of the circuit-breaker, owing to the large current taken by the grounded feeder, is not so simple. Therefore, so-called "inverse time-limit" circuit breakers are generally used; that is, circuit-breakers in which the time limit of their operation decreases with increasing overload. Such circuit-breakers would first cut off the cable carrying the greatest excess current—that is, the faulty cable—and then those of less excess current; but, as the excess current stops with the cutting off of the faulty cable at both ends, other cables should not be interfered with. However, the inverse time-limit circuit-breaker necessarily must be practically instantaneous under short-circuit, and therefore, while the time limit discriminates between 100 per cent or 200 per cent or 300 per cent overload, it cannot discriminate between short-circuits of different magnitude.

Thus, devices become necessary for selecting a disabled feeder and cutting it out without cutting off its parallel feeders or the tie feeders to the substation served by the faulty feeder, regardless of what excess currents these may carry. This is a problem that has not yet been completely solved.

In general, in high-power systems of high standard of reliability the radial system of substation supply is used; that is, each substation is fed by a separate set of cables, and the substations are not interconnected into a network by a system of tie feeders. This radial system, however, is less economical in feeder copper than the interconnected network, since the radial system requires for each substation a feeder capacity equal to the maximum power demand of the individual substation, while in the network, by cross-feeding between the substations, the feeder capacity is reduced to that required by the average maximum demand of the substations. Because of the economic disadvantage of the radial system, an effective selective feeder relay that could be relied upon to pick out the faulty feeder and no other would offer material advantages.

Such a selective device is afforded by the use of pilot cables. Each cable or feeder is duplicated by a smaller low-voltage, three-phase cable, which joins the secondaries of current transformers connected into the two ends of the main cable. If the main cable is undamaged, the same

* From a paper presented at a joint meeting of the Philadelphia Section A. I. E. E. and the Franklin Institute and printed in the July *Journal* of the Institute.

† Chief Consulting Engineer, General Electric Company.

current comes out of it as flows into it, and the connections to the pilot cable are such that in this case the secondary currents would be in opposition; that is, neutralize each other. If, however, the main cable grounds, current flows into it from both sides, the secondary currents in the pilot cable then add, and the current flowing in the pilot cable operates the relay which opens the circuit-breaker. This arrangement is very perfect in operation, and is capable of cutting out the damaged cable without interfering with any other, but it has the disadvantage of doubling the number of cables required in the system. While the pilot cables are small and of low voltage, they occupy room in the underground ducts; hence, this method of control is little used in this country.

Another method is that of the split-conductor cable. Every cable conductor is made of two parts, of which the one surrounds the other concentrically, with some insulation between them. Normally there is no potential difference between the inner and the outer half of the conductor, as they are connected with each other at the ends of the cable. If, however, a ground occurs on the cable, this ground can at first reach only the outer half of the conductor, and a potential difference and current appears between the inner and the outer half of the conductor and operates the circuit-breakers through a relay connected between the halves of the conductor, at either end of the cable. This method also works very satisfactorily, but has the same economic disadvantage,. though to a lesser degree than the method of pilot cables, in that the split-conductor cable is materially larger and more expensive.

The usual method of taking care of the problem, at least in most cases, is by the so-called reverse-power relay, also wrongly called "reverse-current relay." Such a reverse-power relay operates perfectly so long as there is any voltage for the reverse current to act upon. If, however, a short-circuit occurs at or close to the substation, the voltage vanishes, and with it the reverse-power relay loses its pull. To guard against this, the installation of reactances is recommended between cables and substations to give a sufficient voltage drop to operate the relay. However, this is an additional complication.

The reverse-power relay is not adapted to guard the feeders between stations, as in these the current reverses in direction with the change of the distribution of load between the substations. Thus, the reverse-power relay does not make the operation of interconnected networks of substations possible, but in the radial system of operation it is the only device which is generally available economically, and it is very satisfactory with the exception that it cannot operate where there is no voltage left.

Interference by lightning, with high-potential transmission lines, has rather decreased with increasing line voltage. In 100,000-volt lines, the insulators are tested for one minute at 200,000 to 250,000 volts and stand momentarily for the very short time of lightning, over half a million volts. Thus, it is rare that lightning flashes over or punctures the suspension insulators of our very high-voltage transmission systems. A flashover, with the grounded *Y* system, shuts down the circuit, often without any damage, while with the isolated delta system it may not even shut down the circuit, but is taken care of by the protective device against flashovers—the arcing ground suppressor in the station. Most lightning voltages incapable of destroying the line insulation run along the line until their energy is dissipated or they reach a station, and there they often do serious damage. The most important problem of lightning protection thus has become the rapid damping out of line disturbances caused by lightning, so as to make them harmless before they reach the station. The most effective method has been the overhead ground wire. By its screening effect, it lowers the voltage which lightning can induce in the line, but far more important is its powerful damping effect on the line disturbance—the traveling wave caused by lightning which runs toward the station.

In considering the protection of modern electrical systems it must be realized that the various sources and kinds of interference or danger require correspondingly different protective devices. It would be just as unreasonable to expect a standard type of "lightning arrester" to protect an electric system against all possible troubles as it would be to call for a single-standard "safety-device" which would protect a railway train against all possible dangers, from a broken rail or a washout to a collision or a boiler explosion.

The Synthetic Production of Nitric Acid*

THE recent pronouncement of the German Chancellor, and the statements which have appeared from time to time in the daily press and in technical journals, respecting the enormous extension in the methods of transforming atmospheric nitrogen into ammonia and nitric acid, which are claimed to have been developed by German chemical engineers, have attracted such widespread attention at the present time on account of the necessary employment of this acid in the manufacture of explosives, that it may not be uninteresting to explain shortly, and in general terms, the main principles of the methods by which such transformation is effected. The actual details of the manufacturing processes now employed in Germany have not been published, and are not likely to be made known for some time to come. But there is little doubt that these processes are, in the main, merely extensions or refinements of methods already established, and in more or less successful operation, at Odda, Notodden, and Christiansand in Norway, at Legnano, near Milan, at La Roche-de-Dame, in the south of France, and at Niagara Falls. Even before the outbreak of the war, factories for the utilization of atmospheric nitrogen in the manufacture of synthetic ammonia and nitric acid were at work in Westphalia, at Knapsack, near Cologne, at Spandau, and in one or two places in Austria-Hungary. Similar works have been erected, or are in course of erection, in the United States, Switzerland, and Japan.

Although a considerable amount of British capital has been invested in Norwegian enterprises, no attempts have hitherto been made in Great Britain to utilize the vast stores of potentially combined nitrogen which exist in the air. It has been calculated that the air over a dozen acres contains as much potential nitric acid as is annually exported in the form of Chile saltpeter. The apparent apathy of the British manufacturer is probably due to the circumstance that hitherto we have not suffered to any appreciable extent from any shortage of nitrates or nitric acid, and that, so long as we have command of the sea, we are not likely to suffer for some time to come. But it must not be forgotten that the supply of Chile saltpeter is not inexhaustible. The rich deposits of Tarapaca are already worked out, and what is now obtained from the more inaccessible districts of Antofagasta, Toco, and Taltal is of much lower quality. On the other hand, we gather from the Chancellor's statement in the Reichstag that the new industry in Germany is to be protected for at least a number of years, which would seem to imply that the manufacture cannot be worked on ordinary commercial lines. The probable effect of protection would be to limit, if not altogether to destroy, the importation of Chile saltpeter into Germany, and thereby to diminish its price to us unless German syndicates manage to obtain control of the workings.

Another reason for the apparent lack of enterprise on the part of the British chemical manufacturer is the assumption that hitherto the commercially successful working of all such synthetic processes would seem to depend upon cheap water-power, of which this country has no very ample store. But it may be doubted whether this disadvantage is altogether insuperable, at least under certain conditions. At all events, it is certain that the German engineers have to look to other sources of energy. What will be the ultimate effect on the price of nitric acid remains to be seen. In the meantime, it is probable that its present cost to Germany is far higher than to us.

The new methods of making nitric acid from atmospheric nitrogen are twofold in character; either direct, that is, by the direct combination of nitrogen and oxygen, or indirectly through the intermediate production and subsequent combustion of ammonia. The direct formation of ammonia by the union of its elements, nitrogen and hydrogen, has frequently been attempted, but hitherto with very limited success. It has long been known that small quantities of ammonia may be formed by the action of high temperatures, say by the passage of electric sparks, on a mixture of hydrogen and nitrogen. But the action is necessarily incomplete, since it belongs to the class known as reversible, and in ordinary circumstances the yield of ammonia is wholly incommensurate with its cost. But it was found by Haber that when a mixture of 1 part of nitrogen and 3 parts of hydrogen, under a pressure of 175 atmospheres, is heated to about 550 degrees in the presence of a catalyst, about 8 per cent by volume of ammonia is formed, which may be isolated by passing the products through a refrigerating apparatus, the uncombined gases being returned to the compression chamber.

The catalyst first used by Haber was osmium, a comparatively rare metal belonging to the platinum group. Later, finely powdered uranium was employed. Much experimental work has been spent in the effort to find other and cheaper catalysts, in studying the influence of temperature and pressure upon the yields, and in overcoming the technical difficulties inseparable from the construction of apparatus of large size capable of withstanding such high pressures as, say, a couple of hundred atmospheres.

The nitrogen is obtained from the air by the use of a Hampson or Linde liquefying apparatus, and subsequent fractionation on Claude's system; the hydrogen is made by passing steam over red-hot or heated coke. The ammonia is converted into nitric acid by oxidation under the influence of a catalyst. The same principle is adopted in the method of Ostwald, by which ammonia, obtained from "nitrolim," or, as it is called in Germany, "Stickstoffkalk," by a process to be described later, is mixed with air and passed through iron tubes into a chamber containing the contact-agent. The resulting products are led to a condensing plant, whereby, by suitable arrangements, which cannot be here described but are well known, it is claimed that from 85 to 90 per cent of the theoretical yield of nitric acid can be obtained of a strength and purity suitable for the manufacture of explosives. The Ostwald process has been worked for some time at Gerthe, near Bochum, where it is said to have produced upward of 1,800 tons of nitric acid annually; but the experience of other countries where it has been in operation has been far less favorable, and it is doubtful whether a single Ostwald plant is now in use outside Germany.

Up to the present time, the most successful of the factories which have been established for the utilization of atmospheric nitrogen would appear to be that of the North-Western Cyanamide Company, at Odda, on the Hardanger Fiord, Norway. This concern, which is largely financed by British capital, is operated by electrical energy furnished by a water supply capable of producing 80,000 horse-power. This factory and the associated Alby works together produce calcium carbide, and "nitrolim," a mixture of calcium cyanamide and carbon. Pure nitrogen is obtained from the air by a Linde plant driven by a 200 horse-power electric motor, and capable of producing 13,000 cubic feet of nitrogen per hour. This gas is caused to react on calcium carbide (made by fusing lime with Welsh anthracite in electric furnaces) in electric retorts heated to a temperature of 800 degrees. "Nitrolim," by treatment with superheated steam, yields calcium carbonate and ammonia, which latter substance can be converted into nitric acid by combustion, as already stated.

The methods for the direct combination of nitrogen and oxygen to form nitric acid depend upon a reaction first pointed out independently by Priestley and Cavendish upward of one hundred and thirty years ago, and further elaborated, toward the close of the last century, by Sir William Crookes and Lord Rayleigh, who established the theoretical principles upon which the reaction proceeds. They showed that under the influence of a high temperature, produced by electric sparking, or by the passage of a strong induction current, oxides of nitrogen, and ultimately nitric acid, were formed in notable quantity. Indeed, it was in the course of the experiments which served to establish the composition of water that Cavendish incidentally discovered the true nature of nitric acid. But, as the history of science so frequently reveals, although the fundamental discovery was made by English observers, it was left to foreign technologists to turn it to practical account. This was first accomplished by Birkeland and Eyde in 1903, who established a factory at Notodden, in Norway. In their process, air is driven by a Roots blower through a powerful arc flame, operating in a magnetic field, in a specially constructed furnace. At the high temperature of the flame (3,000 degrees to 3,500 degrees) about 1 per cent of nitric oxide is formed, equal to about 30 milligrammes of nitric acid per liter. The actual volume of air operated upon in each furnace is nearly 800,000 liters per minute, and in all about three dozen furnaces are in use. The nitric oxide thus produced is rapidly cooled, when it combines with a further amount of oxygen in the escaping gases to form nitric peroxide, which by treatment with water in absorption towers is changed into dilute nitric acid, to be subsequently concentrated or converted into nitrates.

Various modifications in the mode of producing the arc flame, either with or without a magnetic field, have been introduced by German and Russian engineers, and different methods of absorption and concentration of the acid have been suggested, but the essential principles of the processes are practically identical in all of which published accounts are at present available.

It will be seen from the foregoing statement that the Germans have by no means an exclusive monopoly in the production of synthetic nitric acid, and there is no reason to believe that the modifications they have been able to make in pre-existing processes not of their own invention have placed them in an independent or greatly superior position. It must be remembered that they are at present driven to work under abnormal and utterly uneconomic conditions, and it remains to be seen how far they will be able, as a manufacturing nation, and in the face of the world's competition, to make good their boast that they have rendered themselves permanently independent of outside supplies of nitrates. Their strenuous labors, under the spur of necessity, will at least serve to demonstrate what is to be the ultimate future of synthetic ammonia and nitric acid.

* From *Nature*.

The Manufacture of Liquid Air*

Methods Employed and the Development of Machinery Now Used

THE development of the liquid-air machine is of considerable interest. It is well known that the first investigators to accomplish the liquefaction of oxygen, nitrogen, and air were Cailletet and Pictet, who, working independently of each other, announced their successes simultaneously in 1878. Pictet employed the cascade method; that is to say, by evaporating carbon dioxide at −80 deg. Cent., he was able to condense ethylene under pressure, and to re-evaporate it at −130 deg. Cent., which temperature, combined with a pressure of from 20 to 30 atmospheres, was found to be sufficient to liquefy oxygen. In Cailletet's experiments, on the other hand, no intermediate agent was used. The gas, under very high pressure, was cooled, and was then allowed to liquefy itself by its own expansion Both of these processes, however, were purely scientific *tours de force*, and the first real achievement in making liquid air into a commercial article was the patent taken out by Dr. Carl von Linde in 1895. It is true that this patent was anticipated in this country by the provisional specification taken out by Hampson a few weeks previously, but Hampson's specification was never developed.

Previously to 1895, Siemens, Solvay, and Windhausen had been granted patents for the obtaining of very low temperatures by the expansion of air in a suitable cylinder, the cold expanded air being used to cool the incoming air in a regenerator. But none of these patents, chiefly owing to lubrication difficulties at such low temperatures, was found to be workable. In Linde's invention the lubrication difficulty is avoided. He replaced the expansion cylinder by a simple expanding nozzle, and made the cooling effect obtained by expansion through this nozzle the basis of his process. The cooling effect, discovered in the well-known experiments of Joule and Thomson, is very small, but was found in combination with a good regenerator to be quite sufficient. Actually at 17.1 deg. Cent. there is a drop in temperature of 0.225 deg. Cent. per atmosphere.

The action of the apparatus is simple. Air at a pressure of, say, 100 atmospheres is cooled as far as possible by water, and passed downward through a long spiral of copper tube. At the end of this spiral it escapes through the expanding nozzle, and its temperature at once drops by about 25 deg. Cent. The cooled air then passes up over the outside of the spiral, and in its passage cools the air inside the spiral, which is descending toward the nozzle. The air arriving at the nozzle is therefore colder, and since the expansion through the nozzle makes it colder still, it is clear that a cumulative cooling effect is obtained which will reduce the temperature of the air below the nozzle further and further until it liquefies. Naturally the heat leakage at low temperatures is considerable, but, on the other hand, the Joule-Thomson effect is very much greater.

In actual practice, using a copper regenerator, Linde obtained liquid air after two hours' running, one fifth of a gallon of liquid air being then obtained per hour. The pressures on either side of the throttle-valve were usually 200 and 50 atmospheres respectively.

It was this apparatus which formed the basis of Linde's patent of 1895 for extracting oxygen from air. Since the boiling point of nitrogen is 195.5 deg. Cent., and that of oxygen 181.5 deg. Cent., or 14 deg. Cent. lower, it seemed probable that if liquid air was slowly evaporated, its two constituents might be separated. In actual practice what happened was that vapors rich in nitrogen and oxygen respectively were given off by two different orifices, and by allowing a rather large proportion of the whole liquid air to escape through the first or nitrogen orifice, a gas containing some 50 or 60 per cent of oxygen was obtained through the second or oxygen outlet. To accomplish the slow evaporation an extra coil of copper tube was fitted below the main regenerating spiral, and immersed in a small reservoir, containing the liquid air. The air leaving the regenerator passed into the small copper spiral, and gave up the remainder of its heat in evaporating the liquid air in the bath. It then expanded through the nozzle, liquefied, and dropped into the bath surrounding the spiral. Gradually, as things reached a settled state, the liquid in the bath, owing to the difference in boiling points, became rich in oxygen, while the vapors passing off became rich in nitrogen. The liquid and the vapor streamed over different parts of the regenerator on their way to their respective outlets, and the liquid in its passage turned into the gas rich in oxygen, already mentioned. A noteworthy economy in the process is the cooling of the air approaching the nozzle by that which has already passed the nozzle and been liquefied.

Unfortunately this was the best separation which the apparatus could effect, and pure oxygen was not obtained until the brilliant application by Linde, in 1902, of the rectifying tower. Other ingenious improvements, giving increased economy, have since been made by M. Claude, of the Société de l'Air Liquide, and these two apparatus, the Claude and the Linde, are those at present in use. M. Claude's plant is the more economical of the two, but in the smaller sizes requires rather more constant supervision. There has been considerable dispute, not altogether edifying, as to the merits of the two inventions, and the patents have been the subject of much litigation; but there can be no doubt that the two central discoveries on which the whole process rests—namely, the re-evaporation of the liquid air to separate it into its constituents, and the further separation of these constituents by means of a rectifying tower—are due to Prof. Linde. These two inventions are embodied in his patents of 1895 and 1902 respectively. On the other hand, valuable improvements, as explained below, have been effected by M. Claude, and considerable credit is due to him for his researches in connection with neon lamps, liquid oxygen explosives, and the production of exceptionally pure nitrogen. The whole affair, as regards the inventions themselves, was most ably summed up and elucidated by (the then) Lord Justice Fletcher Moulton in 1908, when passing his judgment on the appeal which was lodged by the British Oxygen Company against the British Liquid Air Company.

Fig. 1.

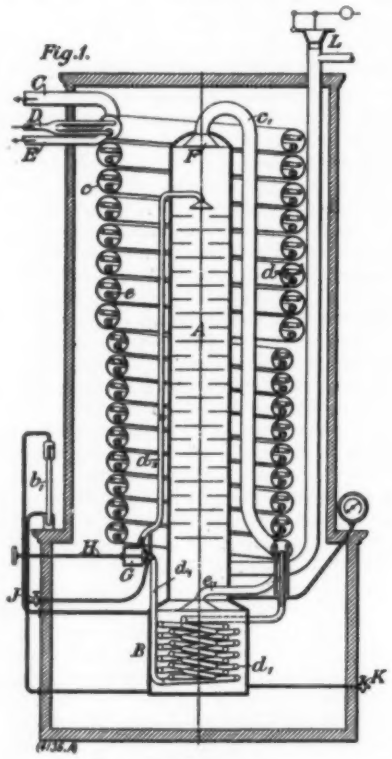
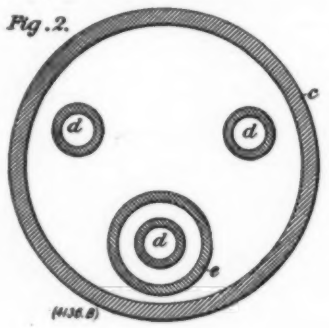


Fig. 2.



The action of the Linde oxygen separator for producing oxygen of 98 to 99 per cent purity will be understood by reference to Figs. 1 and 2. The regenerator spiral, as will be seen from Fig. 2, consists of three small pipes d, inside a large pipe c, one of the smaller pipes d being surrounded by a larger pipe e. The in-coming air is conveyed by the small pipes d to the smaller spiral d_1 which is immersed in the liquid oxygen bath B. From this spiral d_1 the air passes by way of the throttle-valve G to the top of the rectifying column A. Pure oxygen is collected at e_1, and passes through the regenerator by the pipe e to the outlet E. At F nitrogen containing 7 per cent of oxygen is collected, and finds its way through the main pipe c of the regenerator, or interchanger, to the outlet C; b_1 is a gage containing a colored liquid to indicate the level of the liquid oxygen in the bath B, and J and K are test-cocks communicating with the liquid air and liquid oxygen supplies respectively. L is an emergency release-valve on the low-pressure system.

Before reaching the inlet D, which communicates with the delivery of the compressor, the compressed air has been cooled to −20 deg. Cent. by an ordinary refrigerating plant and has been purified of carbon dioxide by a slaked-lime purifier on the compressor suction. The purpose of the forecooler is to freeze out the atmospheric moisture; and if a forecooler is not used, a calcium-chloride drying tower must be placed in the compressor delivery. Even these precautions do not prevent freezing up, so that the forecooler and separator are generally duplicated. In practice, the separator takes about six days to freeze up, and the forecooler about two.

In starting up the plant, air at 2,000 pounds per square inch pressure is admitted at D, after being cooled and purified, and passes through the pipes d and the spiral d_1 to the throttle-valve G, whence it is discharged by the pipe d_2 to the top of the rectifying column A. It finds its way out by the collectors F and e_1, through the pipes c and e of the regenerator, to the outlets C and E. A step down in temperature, owing to the Joule-Thomson effect, takes place at the throttle-valve G, and a progressive cooling goes on till the air liquefies and gradually accumulates in the reservoir B. The pressure of admission is then reduced by degrees to the working pressure of 50 to 60 atmospheres by opening the throttle-valve G.

When the apparatus has steadied down to its work, the liquid air in the bath B is continuously evaporated by the hotter compressed air passing through the spiral d_1, the hotter compressed air being thereby further cooled and liquefied. This is in accordance with the description already given of Linde's 1895 apparatus. The vapors coming off from B will, as mentioned in the same description, be rich in nitrogen, while the liquid remaining will be rich in oxygen, owing to the boiling point of the nitrogen being 14 deg. Cent. below that of oxygen. We have therefore two opposing streams in the rectifying column; a downward stream which starts as liquid air at 81 deg. Cent. absolute at the top (emerging from pipe d_2), and an upward stream which starts as a liquid rich in nitrogen at the bottom, being then at about 91.5 deg. Cent. absolute (the boiling point of oxygen).

The action of the rectifying tower and its baffle plates is to change the descending current into oxygen of 98 to 99 per cent purity, which goes off at the outlet E, and to change the ascending current into nitrogen of 93 per cent purity, which passes through the collector F. In the case of the gases ascending, the oxygen is constantly finding itself in contact with liquids, whose temperature farther up the tower grows lower and lower. It therefore condenses, and joins the downward stream as a liquid. At the same time, the nitrogen in the downward stream, which starts as liquid air, coming into contact with gases that grow warmer and warmer farther down the tower, and which are constantly giving off heat, owing to the condensation of the oxygen, gradually evaporates and passes upwards to the outlet F. The final result is as stated above; and there is, it will be seen, at each stage of the tower, a constant exchange both of substance and heat. The necessary temperature gradient, between 81 deg. Cent. absolute at the top of the tower, and 91.5 deg. Cent. at the bottom, is obtained by means of the Joule-Thomson effect at the throttle-valve G, the pressures on the lower and upper side of this being 50 to 60 atmospheres, and 4 pounds to 5 pounds per square inch respectively. The Joule-Thomson effect also accounts for losses due to leakage through the insulation (which is of sheep's wool cased in with timber) and losses due to the inefficiency of the regenerator. In practice it is found that the pressure of 50 to 60 atmospheres is just sufficient to fulfill all these purposes. It is also far more than is necessary to liquefy the air at the temperature of 91.5 deg. Cent. absolute, which exists in the oxygen bath.

The action of Linde's rectifying tower is similar to, and based on, that of the Coffey still for rectifying alcohol. In the Coffey still the wash, weak in alcohol, was admitted at the top, and steam was admitted at the bottom; while, after rectification, steam passed off at the bottom, and a vapor rich in alcohol at the top, there being, as before, an exchange at each stage both of substance and of heat. In Coffey's apparatus the temperature gradient is provided by the excess in temperature of the steam over the weak alcohol wash, and it is in this respect that Linde's apparatus, by using the throttle-

* From *Engineering*.

valve to give the necessary step-down effect, differs from Coffey's.

It may be asked, Why should nitrogen of only 93 per cent purity be obtained at the top of the tower? The explanation of this fact, and of the action of the tower itself, will be made clearer by reference to the experiments made in 1900 by Baly, on the nature of the evaporation in liquid mixtures of oxygen and nitrogen. In Fig. 3 the Baly curves, which exhibit the results of his experiments, are shown. Baly found that, given a mixture of oxygen and nitrogen in any definite proportion, equilibrium between the liquid and vapor is possible only when the vapor contains a definite proportion of the two constituents; but this proportion is not the same as that in the liquid mixture. The curves show the percentages which exist in the liquid and vapor respectively at various absolute temperatures. For instance, if the liquid mixture is half oxygen and half nitrogen, the vapor in contact with it will, we see from the curves, consist of 22 per cent oxygen and 78 per cent nitrogen. Similarly, when the liquid has the constituency of liquid air—namely, 79 per cent of nitrogen and 21 per cent oxygen—the proportion of oxygen in the vapor coming off will be a little less than 7 per cent. For this reason only nitrogen of 93 per cent purity can be obtained with the Linde rectifying tower described. And it is also easily seen that, since the ascending vapors are always richer in oxygen than they should be for equilibrium with the descending liquids which they meet, there must be a progressive condensation of oxygen from the vapor, and evaporation of nitrogen from the liquid, to enable that equilibrium to be established.

To meet the demand made for pure nitrogen by the cyanamide process, the Linde apparatus had to be modified, when used for producing nitrogen, to the form shown in Fig. 4, used in conjunction with two compressors, for low and high pressure respectively. The main regenerator spiral C incloses three spirals, made from smaller tubing, e, f and d. e conveys the oxygen collected by the pipe e_1 to the outlet e. C conveys pure nitrogen from the top of the tower to the branched outlet C; the pipe d takes the delivery of the low pressure compressor to the liquefying spiral d_1 immersed in the oxygen bath B, and thence to the middle of the column by way of the throttle-valve G, and the pipe d_2; and, finally, the pipe f (which is generally replaced by several pipes) takes the delivery of the high pressure compressor to the liquefying spiral f_1, and, by way of the throttle-valve H and the pipe f_2, to the top of the column. As in the oxygen apparatus, a forecooler and purifiers are used, and there is also a liquid gage j.

The preliminary cooling is effected either by charging the plant with liquid air separately made, or by compressing air at 2,000 pounds per square inch into the pipe f, and, after expanding it through the throttle-valve H, sucking it back again through the pipes C and e. In actual steady operation air is delivered from the low-pressure compressor at 60 pounds per square inch through pipe d, and throttled and discharged by pipe d_2, at the middle of the column, thus rectifying the vapors, which are ascending from the oxygen bath B, till they contain only 7 per cent of oxygen. The rectified vapors escape by the outlet C, and a part of them is taken by a branch to the inlet of the high-pressure compressor. From the high-pressure compressor this portion is delivered to the pipe f, and discharged as a liquid containing 7 per cent of oxygen by pipe f_2 at the top of the column. The effect, according to Bayly's curves, is to rectify the ascending vapors, which have 7 per cent of oxygen when they pass the outlet from pipe d_2, till they contain 2 per cent of oxygen only. A part of the ascending vapors is once more taken from the branched outlet to the inlet of the high-pressure compressor, and discharged by pipe f_2, this time as a liquid containing only 2 per cent of oxygen. The ascending vapors are thus rectified still further, till finally only pure nitrogen is given off. Part of this nitrogen continues to circulate through the high-pressure system for "scrubbing" or rectification purposes, but the major portion is collected for use through the vertical branch on the outlet C. The oxygen vapors meanwhile pass out by pipes e_1 and e.

The advantages of Claude's apparatus are, first, that by a progressive liquefaction of the air, he is able to obtain more complete separation than in Linde's oxygen apparatus; secondly, that by using a part of the incoming air to do work in an expansion cylinder, he obtains his drop in temperature more easily, and can do with an initial pressure of 25 to 35 atmospheres only, thus doubly economizing in power. The saving in power amounts to some 20 per cent, but is partially

Fig. 3.

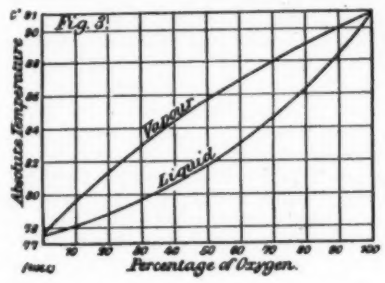
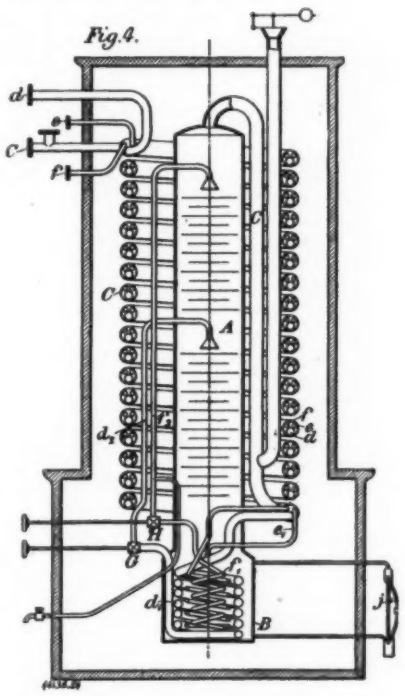


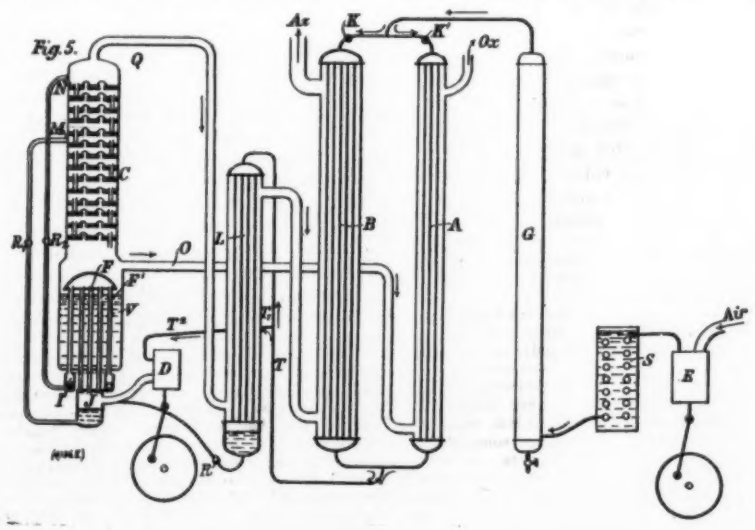
Fig. 4.



counterbalanced by the complication of the apparatus.

Fig. 5 shows the complete Claude plant. Air, after purification in slaked lime, is compressed and cooled, and passing through the calcium-chloride drier G, reaches the two regenerators A and B. The regenerator B, through which the nitrogen passes on its way to the outlet Az, is three or four times as large as the regenerator A, by means of which the oxygen arrives at the outlet Ox. The air at the bottom of the regenerators has a temperature of about −100 deg. Cent., and is then divided into two parts, about a quarter of it going by way of the pipe T_1 to the liquefier L, the function of which will be described later, and the remainder being admitted by a pipe T_2 to the expansion engine D. This engine is used to drive a dynamo, and the lubrication difficulty experienced by Siemens has been overcome by the use of petroleum ether. During expansion the temperature of the air falls to about −170 deg. Cent. (103 deg. Cent. absolute), and its pressure to about 4 atmospheres, which is sufficient to liquefy it at the temperature of 91.5 deg. Cent. absolute existing in the bath of oxygen.

Fig. 5.



Under these conditions the air arrives at the vaporizer V. The vaporizer consists of two sets of tubes, F and F_1, all connected at the top, but opening at the bottom into the receptacles J and I respectively. Air thus passes into J, up the tubes F, down the tubes F_1, and into the receptacle I, and in its passage it becomes liquefied, the part liquefied in the tubes F draining back into the vessel J, and the part liquefied in the tubes F_1 draining back into the vessel I. Vessel I will contain a liquid rich in nitrogen, and vessel J a liquid rich in oxygen. This will be clear if we consider that since the liquid condensing on the sides of the central tubes F is scrubbed by the up-coming vapor as it trickles down, the liquid and the vapor may be said to be in such close contact as to be in equilibrium. Hence, according to Bayly's curves, since the vapor contains 21 per cent of oxygen, the liquid must contain 48 per cent. Of course, the liquid formed in the upper part of the central tubes consists mainly of nitrogen, but as it trickles down the interior of the tubes, exchanges of heat and substance take place between it and the ascending vapors, exactly as in the rectifying tower, so that all the liquid arriving at the bottom contains 48 per cent of oxygen. To this draining back M. Claude gives the name of "retour en arriere." When the 48 per cent liquid is discharged into the rectifying column at M, it naturally produces a vapor which has the same composition as air (21 per cent oxygen), so that the function of the part of the column between M and N is to take out as much of this 21 per cent as possible. This is done by means of the liquid from I, which consists almost wholly of nitrogen, and is discharged into the rectifying column at N. Thus practically pure nitrogen vapor is given off by the pipe Q.

If this pure nitrogen vapor at a temperature of 77.5 deg. Cent. absolute were taken direct to the interchanger B, it would make the air so cold that it would enter the expansion engine mostly in the liquid state. Hence it is passed first through the liquefier L, and in liquefying a part of the compressed air the nitrogen becomes heated itself to −130 deg. Cent. (143 deg. Cent. absolute), and can safely be discharged into the interchanger B.

The compressed air liquefied in this way is expanded through the valve R into the vaporizer, and is known as the "liquide d'appoint." In practice about one third of the air is discharged at M, and two thirds at N, the M supply, as stated above, containing about 48 per cent of oxygen. In the N supply the proportion of oxygen is only about 6 per cent.

By a modification of his apparatus, M. Claude has been able to produce nitrogen of exceptional purity for the cyanamide work, such as is turned out by the Linde process already described. The tubes F and F_1 in this modification are led into one common receptacle instead of into the two separate reservoirs I and J. From this receptacle, as before, the liquid rich in oxygen is discharged at a point, such as M, into the rectifying columns. But the nitrogen, which condenses with difficulty in the oxygen bath in the ordinary apparatus, is taken off from the top of the tubes, and condensed in a small condenser situated about one quarter or one third of the way up the column, where the temperature is cold enough. It is then discharged as a liquid in a high state of purity at the top of the rectifying column, and rectifies the ascending nitrogen vapor to such an extent that they reach the outlet with a purity of 99.8 per cent.

In conclusion, it is interesting to note that the critical temperature of air, above which it cannot be liquefied, is −90 deg. Cent. (170 deg. Cent. absolute), and the corresponding critical pressure is about 40 atmospheres.

The Movements of the Moon

ALTHOUGH astronomers have been endeavoring for over two hundred and fifty years to ascertain the correct movements of the moon, they are still far from having solved the problem. The Astronomer-Royal, in his report of the work at Greenwich during the past year, calls attention to the increasingly big deviation between the calculated position of the moon in the sky and its real position as shown by the Greenwich observations. This deviation has lately been increasing in a serious manner, the error last year being more than twelve times as large as it was twenty years ago, the average annual increase amounting during the two decades to half a second of arc in longitude. The cause of the failure of astronomers to make the moon amenable to their exact mathematics, based on the dynamical laws of gravitation, is believed to be some attractive force of which we are at present ignorant, though in all probability one factor is the true shape of the earth, which still awaits accurate determination.

Mental Tests of Dementia*

A Consideration of Various Doctrines and Results of Some Investigations

By Bernard Hart, M.D., University College Hospital, London, and C. Spearman, Ph.D., University of London

"MENTAL TESTS" signify any mental performances whatever used for diagnosis, provided that they are standardized, that is, arranged so as to admit of repetition by other experimenters or subjects.

Among persons unfamiliar with scientific psychology, there is a tendency to depreciate such tests on account of their usual lack of serious motive. How, it is asked, can the depths of human intelligence be sounded by tasks of obvious triviality? But this is a confusion between the intellectual task itself and its accompaniment of emotion, conation, valuation, etc. The two are so distinct, that a task which to-day seems trivial may to-morrow be clad with intense interest. To render intellectual tests emotional would be a superfluous and, indeed, highly disturbing complication.

A more formidable objection to them is their unsuccessful past. They were given a friendly welcome and careful application by some psychiatrists of first rank, who had to admit that their expectations were woefully disappointed.[1]

This at once brings us to the heart of the present problem. For these investigators, in common with most psychiatrists and psychologists, seem still to retain an essential portion of the old doctrine of "faculties"; they regard mental activity as made up of elements such as "observation," "discrimination," "association," "memory," etc. True enough, they discard the former metaphysical implications and scrupulously replace the discredited word "faculty" by the more modern term, "process"; but they still incline to the generalization implied in the older word, and take their "observation," "discrimination," etc., as functional unities. Many tacitly assume, for instance, that when a person has shown low power of "observing" one class of objects, he will be similiarly inefficient in observing other classes.[2] But when their assumption is thus stated explicitly, it becomes at least questionable.

Even those who stop short of such trenchant generalizations are liable to the same tendency in milder degree. One experimenter, for example, found that the senile dements examined by him could recognize only a comparatively small number of words exposed momentarily to view; on this somewhat slender basis, he erects the general conclusion that such dementia is specially characterized by smallness of field of consciousness. Another writer, on the evidence of one test of the hebephrenic dements under his care, asserts their fundamental defect to lie in their faulty formation of concepts. While a further investigator of the same class of patients concludes on similarly narrow evidence that their real weakness resides in the action of the "over-idea" directing their thoughts. In short, psychiatry—and indeed, almost all current individual psychology—soars lightly to sweeping generalizations, which the slow steps of science could only hope to obtain by arduous research.

Recently, a few psychologists have made a protest. They have realized that to bring two mental performances under such a category as "observation," etc., is merely to find that they resemble one another in the particular aspect denoted by the word "observe"; this aspect is not necessarily more dominant than the countless other ones in which the two performances may differ. But this school, not content with discarding the obviously unwarranted assumptions of functional unity, has gone on to deny functional unity of any kind, and to declare that a person's capacities for completely different performances are entirely independent of one another. Hereby, they have laid themselves open to the reproach of "throwing out the child with the bath," and of reaching a position as clearly opposed to fact as the former one.

It has been left, then, for a third school to pick out and supplement the part truth contained in both the older views. As usual, matters have turned out to be less simple than appeared to any of the earlier theorizers. A very large mass of evidence has been brought to show that a person's success in any intellectual performance may be regarded as the joint product of *two* factors.[3]

The one is "specific ability" for the performance in question with all its particular features. Suppose, for instance, that a schoolboy has surpassed his fellows in the observation of birds' nests. His victory has, no doubt, depended in part on his capacity for the general form of mental activity known as "observation." But it has also depended on his being able to apply this form of activity to the matter of birds' nests; had the question been of tarts in the pastry cook's window, the laurels might well have fallen to another boy. A further influence must have been exercised by the accompanying circumstances; to spy out nests as they lie concealed in foliage is not the same thing as to make observations concerning them in the open light of a natural history museum. Again, to discover nests at leisure is different from doing so under the severe speed limits prescribed by the risk of an interrupting gamekeeper. The boy's rank may even depend largely on the manner of estimating merit; marks may be given either for the gross number or for the rarity of the nests observed; and he who most infallibly notes the obvious construction of the house-sparrow may not be the best at detecting the elusive hole of the kingfisher. Every one of these features of the observation, then—and their number might be indefinitely extended—must be considered as capable of influencing the success of our hypothetical boy; one and all constitute elements of the "specific ability" concerned. Any performance may have a large or small proportion of such elements in common with another performance; in other words, the specific ability for the one may have much or little overlapping with that for the other. Clearly, when the overlapping is so great that the two performances are almost identical, a person's success in one of them must give probability of success in the other also, and the two performances must become highly correlated with one another. Investigation has proved, however, that when two performances have not any such large overlapping, but have in common only the general form of activity as expressed in such words as "observation," this degree of community is *not* sufficient to produce appreciable correlation between the two specific abilities; the latter remain independent of one another.

But overwhelming evidence had recently been brought of the existence of a second factor, whose nature is essentially different. To the extent that this is operative, all intellection whatever forms one single functional unit, power in any one performance going perfectly parallel with power in every other performance, however much they may differ in general form of activity or otherwise. Owing to this factor, any kind of memory, for instance, may show itself to correlate with discrimination, association, conception, etc., as much as, or even more than, with a different kind of memory. This second factor has accordingly been termed by us "general ability."

Thus, while the range of the specific factor is exceedingly narrow, that of the general factor is universal; and between these two there appears to be no intermediate. There are plenty of words, indeed, whose range is of an intermediate character, such as the above frequently quoted "discrimination," "memory," "conception," etc.; each of these denotes a very large group of activities, yet falls far short of embracing all intellection. For many purposes such groupment is serviceable enough. But when considering functional unity, these words only give rise to extremely mischievous and pertinacious illusions.[4]

The theory of "two factors" just delineated, though primarily of psychological origin, has shown itself capable of translation into terms of cerebral physiology; and thereby it seems to gain in clearness and suggestiveness. The specific factor is readily identified with the efficiency of the particular cortical region, or other neural characteristic,[5] co-ordinated to the particular performance in question; so far, we do not transcend the ordinary accepted localization of cerebral function. But the general factor is taken as corresponding to the efficiency of the entire cortex, or some still more extensive neural area; and this is a proposition evidently requiring some justification.

One good reason for this general factor can be furnished without difficulty; this is the fact that various influences affect the whole cortex in common. The chief are its derivation from the same original pair of germ cells, and its nourishment by the same general blood supply. Such conditions common to the whole cortex must tend to produce a common level of excellence in the function of each of its parts; for when the conditions are favorable to one part, they will probably be so more or less to others also. It is on very analogous grounds that the hair of one region of a person's scalp usually resembles that on other regions.

But there is a further reason, one frankly hypothetical, yet perhaps of still greater importance. A number of psychic phenomena—association, fatigue, and above all, "the narrowness of consciousness"—cogently indicate that *each momentary focus of cortical activity receives continual support from energy liberated by the entire cortex* (or some still wider neural area).[6]

Thus far we have given an outline of the "theory of two factors," as it has been developed in normal psychology, and alone appears consonant with the facts elicited by exact investigation of the normal psychic processes. Let us now briefly consider the bearings of this theory on pathology. Take, first, the effect of the fact of the entire cortex having sprung from the same germ cell. Hereby, a tendency must arise for excellence in one part to be accompanied by excellence in other parts, just as in agriculture any soils of common geological origin will be apt to resemble one another in degree of fertility. But such an original correlation between different parts cannot be expected to extend to their subsequent fates; a "static" correlation does not produce a "dynamic" one; neglecting to manure one field will not abolish the fertility of others belonging to the same geological stratum. And in the same way, damage to one region of the cortex—whether by infiltration of blood, by toxin or abscess—will not necessarily extend to other regions.

Take, next the correlation engendered by the different parts of the cortex all depending on the same blood supply. This has, indeed, a "dynamic" character; damage in any cortical region by toxic or insufficiently oxygenated blood will tend to be accompanied by corresponding damage in other regions also. But physiological experience has shown that this inferiority of the blood supply affects the different regious very unequally; usually, in a few places the neurons will be found to suffer from granular degeneration, opaque nucleus, scanty tangential fibers, etc., while everywhere else the changes, if any, will be so minute as to escape scrutiny. Consequently, as far as this influence of the blood is concerned, we should expect any intellectual impairment to show a patchy character, being severe for a few kinds of performances, but having little or no effect on the great majority of kinds. Moreover, this "dynamic" correlation, such as it is, will be limited to maladies arising from intoxication or other diffuse causes. Wherever the cortical injury appears on macroscopic and microscopic examination to be narrowly localized, there we must expect similarily isolated mental injury; otherwise we have to introduce a *deus ex machina* in the shape of extremely hypothetical lesions, so slight as to escape all present means of detection, yet so complete as permanently to destroy function.

All this becomes quite changed, however, if we admit that the activity of any cortical region requires continual support from energy derived from the entire cortex. To some extent, indeed, the mental injury must still continue to run parallel to the lesion; any mental performances directly or indirectly subserved by this particular region must show a precisely corresponding specific disturbance. But over and above this, there must invariably be found a mental impairment far transcending the physiological lesion, extending rather to all intellectual performances whatever. As regards the quality of this general impairment, it should be *independent of the seat of the physiological lesion and of the nature of the malady.* As regards its intensity, *it should most affect just those performances which are*

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* Abstract from a paper published in *The Journal of Abnormal Psychology*.

[1] See, for instance, Kraepelin and Cron, Psych. Arbeiten, II, p. 324.

[2] Whether this inefficiency takes the form of weakened, excessive, or ataxic function, is immaterial for our present purpose.

[3] Brit. J. Psychology, V, 1912, p. 51.

[4] It is not, however, intended to assert that these two factors, specific and general, exhaustively sum up a person's whole intellectual make-up.

[5] In the rest of this paper, to save repetition, we shall simply identify the specific factor physiologically with the efficiency of a particular cortical *region*. But really, this is only one out of the many conceivable particular neural characteristics which may be the substratum of a particular intellectual performance. Pending the decision of physiology on this point, we have chosen cortical regions as certainly applying in some cases (*e.g.*, aphasia), and as being the most readily intelligible. Possibly, some of these specific factors may turn out to be Mendelian units.

[6] For this psychological evidence, we must refer to our previous paper, Brit. J. Psych., V, 1912, p. 67. Nor does the present place appear suitable for discussing the probable mechanism of the supporting action of the entire cortex. It may be mentioned, however, that the belief in such a support has shown itself compatible with very divergent neurological views; it has been combined with the drainage theory by McDougall ("The Physiological Factors of the Attention-Process," Mind, XI, N. S., 1902), with Verworn's theory of interference by *Lehmann* ("Grundzüge der Psychophysiologie," 1912, p. 194), and with neo-vitalism by Walsh ("Psychotheraphy," 1912, p. 133).

shown in the case of normal persons to depend in the highest degree on the "general ability."[7]

In selecting our tests, we aimed principally at obtaining samples from very varied regions of mental activity, so that any general results obtained might have the widest possible range of validity. For this purpose, we took one case of sensory perception, one of quick and accurate usage of well-worn associative paths, one where the activity was of a more elaborately synthetic character, and one depending on wealth and discrimination of ideas.

But, at the same time, we desired also to learn something about the behavior of tests more closely resembling one another. We took, therefore, two tests of memorizing exactly similar except in one single point, and another test of memorizing differing from both in three points only. Also, we arranged three motor tests, one depending in the most simple manner on speed of successive innervations, another involving also some appreciable degree of perceptual activity, and a third requiring delicacy of co-ordination.

COMPARISON OF TESTS MADE WITH ESTIMATES OF INTELLIGENCE.

Our interpretation of experimental results seems to lead to a paradox. The saturation co-efficient of these estimates, giving the degree in which the estimates truly represent the intelligence, amounts only to 0.55, instead of nearly unity, as might have been expected. If we make a direct comparison of the ranks assigned to the patients by the estimates with those assigned by all the tests pooled, the result is still the same, the correlation being only 0.57. The results for the sane subjects are, as far as they go, in a similar direction. All seems to indicate that the estimates form a less reliable guide as to the patient's real intelligence than do several of the experimental tests. This goes even beyond the results of previous investigators. In the work of Abelson, for instance, such estimates were indeed found greatly inferior to the pool of several tests together, but they were distinctly better than any single test taken alone.[8] Burt came to the same conclusion.[9]

To get at the root of this discrepancy between the estimates and the tests, we may begin by considering the sources of error from a very broad point of view. We can scarcely do better than avail ourselves of the masterly words of Bacon: "The mind, darkened by its covering the body, is far from being a flat, equal, and clear mirror that receives and reflects the rays without mixture, but rather a magical glass, full of superstitions and apparitions. Idols are imposed upon the understanding, either (1) by the general nature of mankind; (2) the nature of each particular man; or (3) by words, or communicative nature. The first kind we call idols of the tribe; the second kind, idols of the den; and the third kind, idols of the market."

From the first kind, or idols of the tribe, the tests have never been proved to suffer. Whereas estimates, even when apparently quite independent, have recently been shown experimentally to be influenced by such idols to a remarkable degree.[10]

The second kind, or idols of the den, obviously affect any single test largely; they vitiate it to just the extent that it depends on the particular cortical region involved as opposed to the whole cortex; but their perverting influence diminishes in proportion to the number of tests pooled together. It is wrong, however, to imagine that these idols do not affect the estimates also. Their influence here admits of exact determination, being represented by the correlation between the estimates of different judges of the same persons; this proves in our investigation to be no more than 0.66.

Lastly, from the idols of the market place the tests are clearly exempt. But as regards the estimates, one must agree with Bacon that these idols "give the gravest disturbance." And they are bound to be peculiarly influential in a corporate institution, such as an asylum, where the constant inter-communication, and therefore mutual suggestion, between the members of the asylum staff must inevitably engender a more or less uniform "plane" of general opinion. On the whole, then, these *a priori* consideration are far from confirming the popular tendency to value the tests strictly according to their agreement with the estimates, but rather raise a suspicion that the latter may be the less trustworthy of the two.

Luckily, we are not confined to these *a priori* considerations for explaining the discrepancy between the tests and estimates. Direct light can be obtained by individual scrutiny of the most pronounced actual instances. First, we may pick out the patients who have been rated much lower by the estimates than by the tests; four of them stand out conspicuously from the rest. Every one of them proves to be a case of dementia præcox; this is the very malady where the estimates are subject to a grave under-estimation of ability. Then take the patients who, inversely, have been ranked much lower by the tests than by the estimates; we find only two conspicuous instances; and both are general paralysis, the disease of all others whose ravages are known to go often far deeper than outward appearances would suggest.

But over and above these sources of downright error, the discrepancy between the tests and the estimates may well derive in large part from some real difference in the objects aimed at by them. The tests claim to measure the energy of the whole cortex, a theoretical and purely quantitative matter. But the estimates of "intelligence" can scarcely help having some degree of practical bias; they are likely to measure not so much bare quantity as efficiency, not so much clever as valid thinking. And every psychologist knows that errors of thought arise, not only from stupidity, but even more so from perverted emotion and volition."

METHODS OF MEASURING INTELLECT.

The simplest way is to form an estimate on the basis of natural intercourse, either making some definite observations, or trusting to one's general impression. This has many disadvantages. In particular, the ordinary course of events may not happen to put the person's intellect to any unequivocal trial.

Consequently, the necessity has everywhere been felt of artificially modifying the course of events, so as to bring the person's intellectual power to more distinct expression. The usual procedure has three steps: he is submitted to some sort of examination or test judged by "common sense" as likely to reveal any impairment of "intelligence"; his degree of success is estimated in the light of general experience; and on the basis of one or two such trials, the verdict is formed.

But none of these steps find much support in our experimental results. Our records reveal that "common sense" is but a lame guide as to what tests will exhibit the clearest evidence of mental deterioration. No one, for instance, would have prophesied that of two closely similar tests, one would exhibit nearly the greatest, and the other nearly the least depreciation of ability in insanity.

Further, psychologists are beginning to discover that the conception of "intelligence" is confused and inadequate. For our present purpose it requires replacing by *two* clear conceptions, each needing quite different kinds of test. First, there is the "general ability," equivalent physiologically to the energy of the entire cortex. To estimate this, tests have to be devised in which the influence of the entire cortex plays as large a rôle as possible; and this influence admits of precise measurement by means of our coefficients of "intellective saturation." But since even with the highest obtainable coefficient the influence of general ability never completely ousts that of specific ability, it is indispensable to take the pool of several tests. The bigger the pool, the less will be the relative influence of the specific abilities, and the more clearly visible will be any impairment of the general ability.

But to determine the general ability is not sufficient. In order to diagnose the nature of the malady, we need also to find out the specific mental damage. And in this matter, there appears to be even greater urgency for further investigation. The views now current are not founded upon solid evidence.

The possession of the best tests, however, would be of little use until we knew how to value the patient's success at them. The general impression formed by the experimenter in the light of ordinary experience has been found by us to be treacherous. Our patients repeatedly exhibited errors, incapacities, and other intellectual shortcomings which, at first sight, suggested advanced dementia; but later on, we found just the same to occur with persons of blameless sanity. On the other hand, a patient's performance sometimes seemed remarkably good, until quantitative comparison with the sane showed it really to be poor. An indispensable requisite, then, to the evaluation of all such tests is a full record of similar performances by many normal persons. The not unusual practice of testing for comparison one single normal person appears more likely to mislead than help (Bechterew, *Traité Intern.*, p. 149).

The value of the tests will be greatly enhanced when all psychiatrists have been induced to accept the same ones. The results gained by different experimenters, or in different asylums, or at different dates, will then become comparable with one another. The importance of this unification has been urged in a most convincing way by Sommer. But its speedy adoption can scarcely be hoped for. None of the prevalent methods of testing appear to merit unanimous adoption so much as unanimous rejection.

There is a further and more serious obstacle to obtaining full value from tests, namely, the lack of reliable information concerning the patient's powers previously in health. The pathological impairment has been proved above to be quite similar in nature to the inequalities existing even among normal persons. Hence, we cannot measure how much an intellect has been affected by malady unless we know how great it was in health. It has been suggested that only such tests should be used which all normal persons without exception can execute (Ziehen). But this would limit consideration of dementia to the grossest, least interesting cases. The difficulty applies in especial degree to specific abilities; for these differ so widely in health, that even the most extreme incapacity furnishes uncertain evidence of pathological deterioration.

It remains expressly to disclaim exceptional virtue for the tests employed in the present investigation. They were chosen, not as models of excellence for practical use, but as the most likely to illumine the matter and thus prepare the way for making excellent ones in the future. The chief requirements turn out to be: convenience of application, adequate reliability coefficients, and high coefficients of intellective saturation. Now, all our present tests are fairly convenient; most of them have pretty good reliability coefficients; but the only ones with tolerable coefficients of general ability are quality and quantity of sentences, accuracy and speed of figures, accuracy and speed of addition, and perhaps speed of crossing-out rings.

An abundance of other tests will be found in the recent literature (especially in Whipple's "Manual of Mental and Physical Tests"). It is required to make convenient selections and modifications, and then to determine their coefficients of reliability and of intellective saturation. Not till this has been done will it be possible to pick out really good tests of general ability.

FURTHER ASPECTS OF THE INTELLECT.

The facts discussed in the present paper have been found to be incompatible with the usually assumed functional unities, which are simply the old "faculties" masquerading under new names; they can only be explained by the theory of general and specific abilities. But this by no means implies that these two factors constitute a complete characterization of the intellectual make-up of individuals.

To begin with, all the test performances are what may be called maximal; they show what the subjects can do under such a strong stimulus as the experimenter's exhortation to try their hardest. But it cannot be expected that such strenuous efforts should have a course closely similar to that of ordinary life. For instance, although the specific correlation between the *powers* of speed in different performances has been found to approximate to zero, this need not necessarily be at all the case as regards *preferences* of rate; on the contrary, the person who likes to do one thing in a deliberate manner is very likely to prefer deliberateness in other things also.

Then again, our tests were of such short duration as practically to eliminate the influence of fatigue, though this under other circumstances may be very powerful. It has, indeed, been shown recently by Flügel that fatigue, like ability, is either of the whole cortex or else of some very particular cortical region;[11] but there is no ground for assuming that the person with greatest momentary supply of cortical energy will also possess the most enduring supply.

Also, many further factors have been stated to characterize the intellection of individuals, such as "preservation," "span of consciousness," etc. The great majority of these statements are merely guesses or illicit generalizations; but a few of them are probably true and very important.

Furthermore, it will be noted that our cases are far from exhausting the whole field of mental diseases. The classification of insanity at the present day is so unsettled, and the specific mental diseases generally recognized are so ill-defined, that we have felt it to be unprofitable to attempt refinements of diagnosis. Only well-marked instances of commonly accepted clinical diseases have been selected for the purpose of the tests, and even with regard to these it must be clearly understood that the few comments we have ventured to make as to distinctions existing between various diseases have only a very limited and provisional value.

Finally, these tests have been arranged so as to be confined to purely intellectual factors. But in ordinary life, this simplicity is of rare occurrence; for the most part, what we think and believe is dominated by what we feel and want.[12]

CHIEF CONCLUSIONS.

1. Our experimental results appear incompatible with

[7] A discussion of the probable reason for some performances depending more than others on general ability, will be found in Brit. J. Psych., V., 1912, p. 69.

[8] Brit. J. Psych., IV. 1911, 305.

[9] Brit. J. Psych., III, 1909, p. 159.

[10] See Marbe on "The Uniformity of Psychical Occurrence," Kongress für Exp. Psychologie, IV, 1912.

[11] Much light on this matter will be furnished by an investigation of Mr. Webb shortly to be issued from the laboratory of one of us.

[12] Brit. J. Psych., VI, 1913, p. 60.

[13] A good illustration is furnished by W. McDonald in his "Studies in Dementia," Proc. Am. Medico-Psych. Asso., Boston, June, 1906, p. 248.

the current view that dementia consists in large "defects," "gaps," "hyperfunctions" or "ataxias" in mental power, such as "disturbed association," "faulty judgment," "weak power of conception," "poverty of ideas," "loss of memory," etc. For the inequality between the powers of the same person for different kinds of performance does not appear to be appreciably greater in insanity than in health, nor in one of the forms of insanity tested than in another. Thus, in the main, the mental injury appears to be of a perfectly diffuse character or to constitute a lowering of the whole intellectual level. The fallacy of "defects" would seem to derive from taking as effects of the malady what are really perfectly normal differences between a person's powers for different performances. These misapprehended weaknesses have, further, been unduly generalized; a poor ability in some particular operation involving memory has been illegitimately taken as inefficiency of memory as a whole.

2. Over and above this general impairment, elaborate methods can also detect certain damages characteristic of particular maladies. These are very narrow and specific in kind, but probably may be correspondingly grave in intensity.

3. The sole theory capable of accounting for these and other results appears to be that already reached in the experimental investigation of normal persons. According to this, every intellectual performance depends on *two* physiological factors: the particular region or characteristic of the cortex which is the direct substratum of that performance; and secondly, a reinforcement or other support derived from the entire cortex. It is the latter factor whose impairment produces all of the more readily observable signs of dementia. The intellectual damage arising from the former factor is most difficult to detect, just as is known to be the anatomical factor itself. It is very unlikely to be manifested on any mere casual examination. These specific mental injuries offer a large field urgently needing exact investigation.

4. This correspondence between the normal and pathological results has been found susceptible of an extremely crucial verification. Among normal subjects, the degree of dependence of any intellectual performance on the efficiency of the entire cortex as opposed to the specific substratum can be brought to quantitative measurement (in the coefficient of "intellective saturation"). The value obtained proves to be strictly proportional to the degree that the performance is depreciated in insanity.

5. The importance of this theory of two factors in ability may be exemplified by the strife of centuries concerning cerebral localization. The one school, as exemplified by Munk, has its eyes on the specific factor alone; while the other, with Goltz, has persistently had in view the general factor. The possibility is now dawning of a scientific reconciliation, in the shape of a quantitative estimate of both factors.

6. As regards practical diagnosis, the method of mental tests appears to be already capable of accurately determining any person's general level of intellectual power. But before accurately measuring the impairment (especially in slight cases) we require to know how great this power was in health. The determination of the specific depreciation characterizing particular maladies remains almost wholly a matter for future investigation.

7. In addition to general and specific ability, there probably remain further highly important constituents of individual intellectual make-up.

The Use of Aluminium in War*

A LONDON newspaper recently reported the seizure, by the Norwegian authorities, of 170 tons of aluminium, which had been shipped indirectly to Germany from a neutral country. Hundreds of tons of aluminium have entered Germany from Switzerland and by way of Barcelona and Genoa, and the German submarines in the North Sea take good care not to sink vessels laden with aluminium or with copper.

Germany is in need of aluminium, and the recent rise in the price of the metal is significant. At the beginning of this year aluminium sold for about $400 a ton. This price was fixed by the international syndicate, which was founded in 1908, when the French producers rejected the old agreement which assured the domination of the German-Swiss works at Neuhausen. In June the price of aluminium had risen to $700 a ton. This increase does not appear to be due to any increased demand by the Allies, who use little aluminium for those military purposes which are now most urgent and important. The French producers, who are bound by their contracts, derive no benefit from the increase, which goes to enrich intermediaries, who load the price with problematical risks.

Pure aluminium does not seem to merit attention for its mechanical properties. It is very soft and weak, and apparently too light to be employed in artillery. In France, where the aluminium industry was founded by the researches of Sainte-Claire Deville, the metal has been tried as a material for cartridges, shells, fuses, and camp and kit utensils. It was rejected by the artillery service and has not yet been adopted by the commissariat.

In Germany and Austria, on the contrary, aluminium has been employed and accumulated in enormous quantities, in preparation for war, and the rapid increase in the world's production of aluminium is due chiefly to this fact.

THE WORLD'S ANNUAL PRODUCTION OF ALUMINIUM.

Year.	Tons.	Year.	Tons.
1900	7,300	1907	18,800
1901	7,500	1908	19,600
1902	7,800	1909	24,200
1903	8,200	1910	44,200
1904	9,300	1911	46,800
1905	11,500	1912	61,100
1906	14,500	1913	70,000

The increase of 4,000 tons between 1900 and 1905 may be attributed mainly to the rise of the automobile industry, but the increase continued after the check experienced by that industry in 1905, which was the year of the Algeciras conference, and a sudden increase of 20,000 tons in a single year followed the Agadir affair in 1909.

For a number of years the Germans and Austrians have used aluminium in the construction of the fuses of their shells, the canteens, pots and cups of their soldiers, and the frames of their Zeppelins. Some of the fuses are made entirely of aluminium, others are composed of aluminium and brass. Assuming that each fuse contains 400 grammes of aluminium and that 15,000,000 fuses—a very moderate estimate—were constructed in advance, the aluminium stored up in the form of fuses would amount to 7,000 tons, which, owing to the unavoidable waste in working, represent nearly 8,000 tons of aluminium bars. It would be prudent to accumulate twice this quantity, in addition, in order to replenish the stock of fuses, and we may be sure that this precaution was taken by the methodical and provident Germans who employ a metal of so recent introduction, although they possess neither its ore (bauxite) nor abundant water power for its production. These considerations indicate a consumption of 24,000 tons of aluminium for the artillery service alone.

The soldier's individual pot, cup and canteen would require 700 grammes of aluminium, so that the equipment of five million men would require 3,500 tons, representing nearly 4,000 tons of aluminium in bars.

Each Zeppelin contains from 6.5 to 9 tons of aluminium and thirty Zeppelins are known to have been constructed, so that at least 250 tons of aluminium have been used in this way. It is impossible to estimate the quantity reserved for the construction of new Zeppelins and the equipment of fresh troops.

A few months before war was declared the German war ministry was experimenting with aluminium alloyed with 3 per cent of copper and 1 per cent of magnesium. This alloy, called duralumin, which is four times stronger and 30 per cent more extensible than pure aluminium, was used experimentally as a material for shells and cartridges. A little later it was proposed to adopt an ingenious infantry shield, made in Austria. The shield was composed of a plate of hard steel backed by a plate of duralumin. The two plates were riveted together and either of them could be covered with canvas. The shield could be carried on the left fore-arm by means of two straps. Such a shield would be lighter than the sand-bag used by French soldiers, and it could be managed with one arm, leaving both hands free. The hard steel face and soft back would give it the peculiar efficiency of a plate of Harveyized steel. For the same reason, duralumin would have been an excellent material for helmets.

Without regarding these experiments or the ordinary uses of aluminium we reach a minimum consumption of 30,000 tons.

The Germans have also contemplated the substitution of aluminium for copper, of which they are greatly in need, despite diligent working of the Mansfeld mines, the pillage of Belgium and the capture of the French copper district of Dinanderie, and the seizure of German stocks of copper destined for other uses.

German shells ringed with aluminium have been found. Pure aluminium, which is softer than copper, would fill the rifling grooves and foul the guns. The filling of the grooves might be prevented by hardening the metal and guns fouled by aluminium could easily be cleaned with hot solution of caustic soda, whereas copper cannot always be removed without deforming the rifling.

The Germans are endeavoring to secure aluminium in every possible way. Toward the end of last year Prof. Otto N. Witt stated, in the *Chemiker Zeitung*, that the aluminium industry chiefly used French bauxite and that it would be necessary to turn to a similar ore, found in Dalmatia. He suggested the idea of obtaining aluminium nitrate and alumina from kaolin by the Ottokar Serpek process. The ammonia disengaged in the conversion of the nitrate into alumina could be fixed in the form of ammonium sulphate and used as a fertilizer. It would then be possible to requisition all the agricultural stocks of Chile nitrate. Aluminium, alumina, even bauxite, have been smuggled into Germany, either for new military uses or to feed the electric furnaces, whose number and output may have been increased, despite the lack of water power, by utilizing electric power derived from the coal made available by importation from conquered fields and by the diminution of German exports.

* Abstract of Nicolas Flamel's article in *La Nature*, July 31st, 1914. Translated for the SCIENTIFIC AMERICAN SUPPLEMENT.

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